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FINAL REPORT 2175 MODULAR RADAR PROJECT

A. G. PAGE

30 JUNE 1975

Research and Development June 1974 through June 1975

Prepared for
Naval Material Command

NAVAL ELECTRONICS LABORATORY CENTER
San Diego, California 92152

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Investigations and analyses were conducted on the feasibility of adopting Standard Electronic Modules as building blocks for surface-search radars. Results of the study indicate the substantial costs savings in radar down times, repair times, and automatic fault isolation can be realized. Procurement costs of modular radar systems are shown to be substantially less than for systems which must be designed anew.

ADMINISTRATIVE INFORMATION

The work reported upon herein was performed by the Radar Systems Division of the Electromagnetic Technology Department, Naval Electronics Laboratory Center, as part of the 2175 Modular Radar Project for the Naval Material Command under task 62762N, F54545,ZF54545001 (NELC Z401-1). The author wishes to thank the many individuals at NELC, NAFI, NAVSEA, NAVMAT, NAVSEC, and NAVELEX who helped make the project a success. In particular, the following individuals made substantial contributions to the effort: C. W. Erickson, M. E. Nunn, R. D. Strait, and J. L. Whitaker (NELC); D. Grayson, C. A. Hughey, E. Hauschild, and D. Weidner (NAFI); T. Ducklow (NAVSEC NORDIV); D. Thackston (NAVSEA consultant); LDCR Boyle (NAVSEA); and LCDR R. Birchfield (NAVMAT).

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INTRODUCTION

The United States Navy has well over a hundred different radars in its current inventory of supportable systems. In the surface-search category alone there are over twenty nine different radars in active use. Many of these radars perform essentially the same functions with varying degrees of success.

Of prime concern in the operation of these equipments is a figure of merit called Operational Availability (A_o). This figure expresses the percentage of time the radar is functioning properly with regard to operating demand time. Excluded from this calculation, of course, is the time when radar operation is not required, such as when the ship is in port.

Typically, radar systems achieve A_os between 30 and 40 percent. These A_os reflect many factors such as mean-time-between-failure (MTBF), mean-time-to-repair (MTTR), availability of repair personnel, availability of repair parts, and other miscellaneous factors such as the ease by which technical manuals can be used for fault localization. In addition to attempting to raise the A_o figure to its highest level, the problem of logistically maintaining this large number of unique radar designs adds to the overall scope of the task.

In an attempt to come to grips with the problem, the 2175 Modular Radar Program was established with the goal of achieving a two-to-one improvement in areas such as reliability, maintainability, and operational performance by utilizing state-of-the-art fabrication techniques such as microelectronics and modular construction.

Almost at the outset, the definition of a two-for-one improvement was found to be difficult to put into words. For example, would a doubling of output peak power be a two-for-one improvement even if it required tripling the prime input power? Or would cutting repair time in half be such an improvement even if the part used for repair cost four times that of other part types? Finally, a criterion was agreed upon. A radar system would be developed which would show a two-for-one improvement in overall life-cycle costs and would, at the same time, meet all of the operational requirements within a suitable time frame.

RADAR SURVEY

To establish performance requirements for the modular radar, a survey was made of all radars in the Navy's current inventory. For purposes of the 2175 Program, it was decided to limit the scope of the survey to the surface-search radars and show the feasability of achieving a two-for-one cost saving in that area before attempting more sophisticated designs.

It was found that 29 different search radar designs are in active status. Further, if all of the mods of these 29 designs are taken into account, there are indeed, 53 different systems designs in use. These cover two frequency bands and produce peak output powers from 10 to 270 kilowatts. These radars were found to meet needs in four categorical areas: Type I, Major Combatant; Type II, Precision Navigation; Type III, Major Auxiliary and back-up for Type I; and Type IV, Small Boat.[1]

The objective of the 2175 Program then became one of designing a family of surface-search radars which would meet all of the Navy's performance requirements, reduce proliferation, and increase the A_o of systems to achieve substantial cost savings.

1. Chief of Naval Operations OPNAV Instruction 09670.2A, Ch. 1, Ship Type Electronics Plan, 1 October 1972.

While it was obviously desirable to reduce the number of systems to one and thereby have the simplest possible logistics support, it was also obvious that the long-range requirement for major combatants was not compatible with the small size and minimum power-drain requirements for the small boat. Accordingly, the project was directed to produce a family of radars that could meet the four type requirements and, at the same time, demonstrate a high degree of commonality of functional sub-systems, such as the use of the same i-f strip in all systems, the same magnetron modulator, or the same timing and control section.

The starting point was to list the basic parameters for radar systems which would meet the four type requirements. These parameters are listed in table 1. One of the first items to become apparent was the similarity of Type I (X-band) to Type III, and Type II to Type IV. This meant that two X-band designs could meet four type requirements. It was also decided to include a C-band Type I system for three reasons. First, the AN/SPS-10 C-band radar is the most popular Type I radar in the Fleet. Second, for retrofit considerations, it would be very desirable not to require replacement of the waveguide run and antenna. Third, it was desired to demonstrate commonality of functional groups across frequency bands as well as across power levels.

This document describes how well these objectives have been met. A supplement will be published about December 1975 and will present the results of the evaluation scheduled to be completed in October 1975.

TABLE 1. BASIC PARAMETERS FOR SURFACE-SEARCH RADARS.

TYPICAL RADAR	TYPE I AN/SPS-10	TYPE I AN/SPS-55	TYPE III AN/SPS-60	TYPE II & IV LN 66
Freq. Band	C	X	X	X
Peak Power (kW) (Minimum)	190	130	35 – 75	10
Pulse Rate	625-650 pps	750-2250 pps	750-1500 pps	1250-2500 pps
Pulse Width	0.25-2.5 μsec	0.12-1.0 μsec	0.1-0.5 μsec	0.05-0.5 μsec
Power Tube Type	Magnetron	Magnetron	Magnetron	Magnetron
I-F Freq.	30 MHz	60 MHz	60 MHz	45 MHz
Bandwidth	1-5 MHz	1.2-10 MHz	2-12 MHz	14 MHz
Noise Figure	14 dB	10.1 dB	7 dB	11 dB
Input Power	115V 60 Hz 3 Phase	115V 60 Hz 1 Phase	115V 60 Hz 1 Phase	115V 60 Hz 1 Phase, or 12-36 Vdc

MODULARITY

One of the basic philosophies to be applied in the 2175 Modular Radar Program was that the radar would be built using a modular concept. No specific definition was applied to a module but the general philosophy of the module approach was given in the Phase I Report.[2] Additional background, over and above that contained in this document, may be secured from that report.

STANDARD HARDWARE PROGRAM MODULES

An investigation was made of the various modular formats which would be suitable for the 2175 Program. Included in this investigation was the family of Standard Hardware Program (SHP) modules. These modules became the choice for the 2175 modular radar for the following reasons:

First, these modules are already in the Navy logistics supply system and are not only approved for use in Navy electronic systems but are required to be used by a NAVMAT directive.[3]

Second, these modules have high proven reliability. Significantly, only in a very few cases has the actual reliability of the SHP modules been found to be less than the predicted reliability prior to implementation. This fact speaks highly of the attention to quality and detail which was given by NAVELEX, NAFI, and NAD Crane in pursuing the program. It also points to the high degree of confidence that new development modules, required for the modular radar, would also perform as dependable components.

Third, the plug-in feature of these modules would lead to more rapid repairs of downed systems. Concern was indicated in this area since connectors are currently thought to be the weak link in electronic systems. Investigation into this possible problem area revealed that the SHP connector was engineered so as not to be a source of concern. The solder connections on the etched circuit boards (which are as good as present techniques allow and which exist in all electronic systems) were more of a problem than the connectors themselves. It was felt that the effect the connectors would have on overall reliability would be more than offset by the relative ease of repair and the attendant lower mean-time-to-repair (MTTR). An explanation for the small number of failures experienced in the module connectors possibly lies in the high reliability of the modules themselves. It is well known that multiple insertions and extractions are the prime causes of connector contact problems. A module having a mean-time-before-failure (MTBF) of 0.1×10^6 hours would theoretically require replacement every 11.4 years. At this rate, the connector would last longer than the equipment would likely be used. The modules used in the 2175 radars have typical MTBFs of about 0.5×10^6 hours.

Fourth, these modules provide elementary functions which have a wide range of applicability. Circuits presently in the SHP system are largely digital such as multiple-input AND gates, flip-flops, multivibrators, shift registers, and the like and, as such, are used extensively in all digital systems. Many analog circuits are also available such as OP-AMPS, oscillators, buffers, and voltage regulators. These circuit modules have a nature elementary enough that their range of application is not just across a family of radar sets but encompasses all types of electronic systems. The advantage in logistic support is readily recognized. At present,

2. Naval Electronics Laboratory Center Technical Report 1911, Project 2175 Phase I Report, March 1974.
3. Office of Naval Material NAVMAT Instruction 4120.102B, Standard Electronic Module Program (SEM), undated draft).

there are over three million of these modules in active use in some 76 different Navy electronic systems. As of November 1974 there were 238 approved SHP circuit functions available for selection in new designs.

Fifth, one large problem area in present electronic systems is that of repair of failed systems. The various levels of repair, problems of component storage and shipping, training of repair personnel, and administration of systems has caused attention to be given to a throw-away-on-failure concept. The SHP Program has, since its inception, been guided in this direction. The average cost of an SHP module is about $60 and thus falls well below the $150 to $200 figure usually mentioned as the maximum value for throwaway. Also worth mentioning is that, even though SHP is considered a throwaway, NAFI has requested that failed modules be returned for failure analysis. At this time in the program, this is a desirable action as it will reveal high-failure items and allow the initiation of corrective designs. Somewhere downstream, this requirement will be abandoned as more confidence is achieved for specific modules.

All these considerations, taken together with the desire not to become involved in any high-risk development of some new modular concept, directed the 2175 Modular Radar Project to take advantage of existing SHPs. It is interesting to note that, although no shipboard radar system has ever been implemented using SHP, the final design for the 2175 Modular Radar achieved about a 40 percent utilization of previously existing or in-process approved SHP modules.

It should be noted here that the official nomenclature for SHP was changed to Standard Electronic Module (SEM) by Chief of Naval Materiel (CNM) in February 1975. All further reference to the modules in this document will, for this reason, use SEM instead of SHP.

COMMONALITY

One very important feature of the design for the 2175 Modular Radar is its commonality. The design has achieved not just commonality within itself but across system lines as well. The intrasystem commonality will be discussed later (Description of Equipment). There is also a present intersystem commonality as shown by the 40 percent already existing SEM modules which are incorporated in the radar design. These are presently being used in 28 Navy electronic systems. A listing of these systems is contained in Appendix A.

It should be recognized that, while over three million SEM modules are in use, this figure represents only a very small fraction of the potential use if the directive to use SEM in new system designs were to be more stringently followed. It can be envisioned that all Navy electronic systems such as communication systems, command and control systems, radar systems, and sonar systems, could eventually have a high degree of common parts.

The advantages of lower costs due to increased production runs of modules, easier logistics support, and better availability of repair parts (one module might support ten different systems aboard ship) can be readily recognized. The possible financial savings and increased operability with a full implementation of SEM in all electronic systems is beyond calculation.

FLEXIBILITY OF DESIGN

When modular concepts are mentioned, an objection is often raised that "the use of standard modules unduly limits the technological advances that could be made." In other

words, if one requires the use of standard electronic modules will one obtain a system which cannot take advantage of present and future technological capabilities?

Two answers are apparent and have a direct bearing on the subject. First, once a radar is designed and released to production, we, as developers of systems, are tied into that system's technological design for its life span. Second, improvements to existing systems are costly. In the final analysis then, the answer to the question is negative. A properly designed modular format will enable the updating of the current state-of-the-art with minimum cost and time, and there is no inherent limitation in circuitry or components.

The SEM Program specifies form, fit, and function without dictating the circuitry to achieve these. The manufacturer is allowed to use any fabrication technique and circuit, including new microcircuit designs, to achieve the function. The only requirement is that NAD Crane approve the design as meeting the form, fit and function requirements. In the event that a design does not exist in the SEM inventory of modules, a manufacturer can submit his design to NAFI for approval and inclusion in the SEM listings.

In addition to this open road for current technology in original system design, there also exists the very real advantage in the redesign of an existing module, such as an i-f amplifier strip, using new devices within the module which would improve its performance and by simply replacing an existing plug-in module with the improved one, achieve increased performance without requiring a whole new radar design.

While this will require foresight (which is never 20/20), consideration should be given, and has been given in the 2175 Program, to potential candidates by leaving extra room in the event additional space would be required by the improved designs.

Under the heading of flexibility, it should also be noted that in the design of the system, there exists much wider capability than is being used in the digital areas such as timing functions and built-in test equipment (BITE). These areas can be expanded or modified by backplane wiring changes or by using new modules for possible future requirements.

GENERAL REQUIREMENTS

PERFORMANCE

Since no published operational requirements for the radar system existed at the inception of the 2175 Program, the general requirements to fill the four type classifications were developed by looking into present system capabilities and adding, within reason, any obviously desirable features. As a result, the AN/SPS-10 and AN/SPS-55 radars were selected as representative of Type I, the LN-66 was selected as representative of Type II, the AN/SPS-53 and AN/SPS-60 were selected as representative of Type III, and the LN-66 was selected as representative of Type IV. From these, the general operating parameters given in table 2 were established.

Two areas require some discussion. First, there is a drop of about 40 percent in output power for the modular, Type I, C-band system from that of the AN/SPS-10. The 170 kW figure was selected for the 2175 Modular Radar for the following reasons:

1. The AN/SPS-10 achieves an output power of 285 kW only at band center and drops off to about 170 kW at band edges.

2. The noise figure of the AN/SPS-10 is about 14 dB and, for the 2175 Modular Radar, a 10-dB figure can be obtained using off-the-shelf components which would

TABLE 2. RADAR OPERATING PARAMETERS.

	AN/SPS-10	I-C	AN/SPS-55	I-X	AN/SPS-53	IV-X_1	LN-66	IV-X_2	AN/BPS-15	IV-X_{sub}
P(kW)	285	170	130	130	35	10	10	10	35	10
Bandwidth	1 & 5	1.2 & 12	1.2 & 10	1.2 & 12	4 & 12	1.2 & 12	14	1.2 & 12	4 & 12	1.2 & 12
PRF	650	4K & 1K	750 & 2.5K	4K & 1K	750 & 1.5K	4K & 1K	800 & 2.5K	4K & 1K	750 & 1.5K	4K & 1K
Pulse Width	0.25 & 1.3	0.1 & 1.0	0.12 & 1.0	0.1 & 1.0	0.1 & 0.5	0.1 & 1.0	0.05 & 0.5	0.1 & 1.0	0.1 & 0.5	0.1 & 1.0
T_x Freq.	5.5	5.5	9.5	9.5	9.4	9.4	9.4	9.4	8.8	9.0
NF	14	10	10	10	11	10	11	10	10	10

more than offset the lower power output as far as the minimal-detectable-targets figure was concerned.

3. It was found desirable to use the same modulator for both the high-power X-band and C-band transmitters. However, due to the difference in driving-point impedances of the two magnetrons, this could not be achieved. A common modulator is still a viable concept but it will require the development of a new magnetron and this is outside the scope of the 2175 effort.

The second point of difference shown in table 2 is the 130-kW X-band radar for the Type III category versus 35 kW for the AN/SPS-53. The modular 130-kW system could be packaged in less volume than the AN/SPS-53 and, since ships using this type do not have a critical prime power limitation, the decision was made to use essentially the same radar as the Type I for this Type III application, giving a higher power capability and reducing the number of unique radar sets. Subsequent to this decision, NAVSEA 0652 determined that the Type II 10-kW system can handle this requirement. In either case, the Type III is identical to one of the other types.

DESCRIPTION OF EQUIPMENT

GENERAL OVERVIEW

The family of surface-search radars must include systems sufficient to fill the four type requirements of NAVSEC. The 2175 approach to this problem was to design the systems in such a manner so as to achieve the greatest degree of commonality. In line with this approach, five levels of modularity were defined and are shown in figure 1. The intention was to be able to use any level as an interchangeable module. Or, to put it another way, to be able to use common components (resistors, capacitors, etc.) on different SEM modules, use common SEM modules such as the key coded FHA (binary counter) in different sections, use various sections to build different groups, use common groups (receivers or built-in test equipment (BITE) to construct different sets.

The performance specifications for the four types then led to defining the groups which would be needed for the construction of each of the four types. Twelve group-level modules or building blocks were defined as follows:

1. One receiver, used in all sets.
2. Three transmitters, C- and X-band high power, and X-band low power.
3. One signal processor.
4. Two power supplies, one 115 Vac and one 28 Vdc.
5. One built-in test equipment (BITE).
6. One timing and control.
7. Three microwave, C-band high power, X-band high power, X-band low power.

Although the list shows three transmitters, it should be noted that the 21 SEMs used to construct the Type IV system are all used in the Type I system. The Type I transmitter required seven additional modules to perform the BITE function. Also, in the two power supplies, the Type I uses 15 SEM types of which only two are not found in the Type IV system.

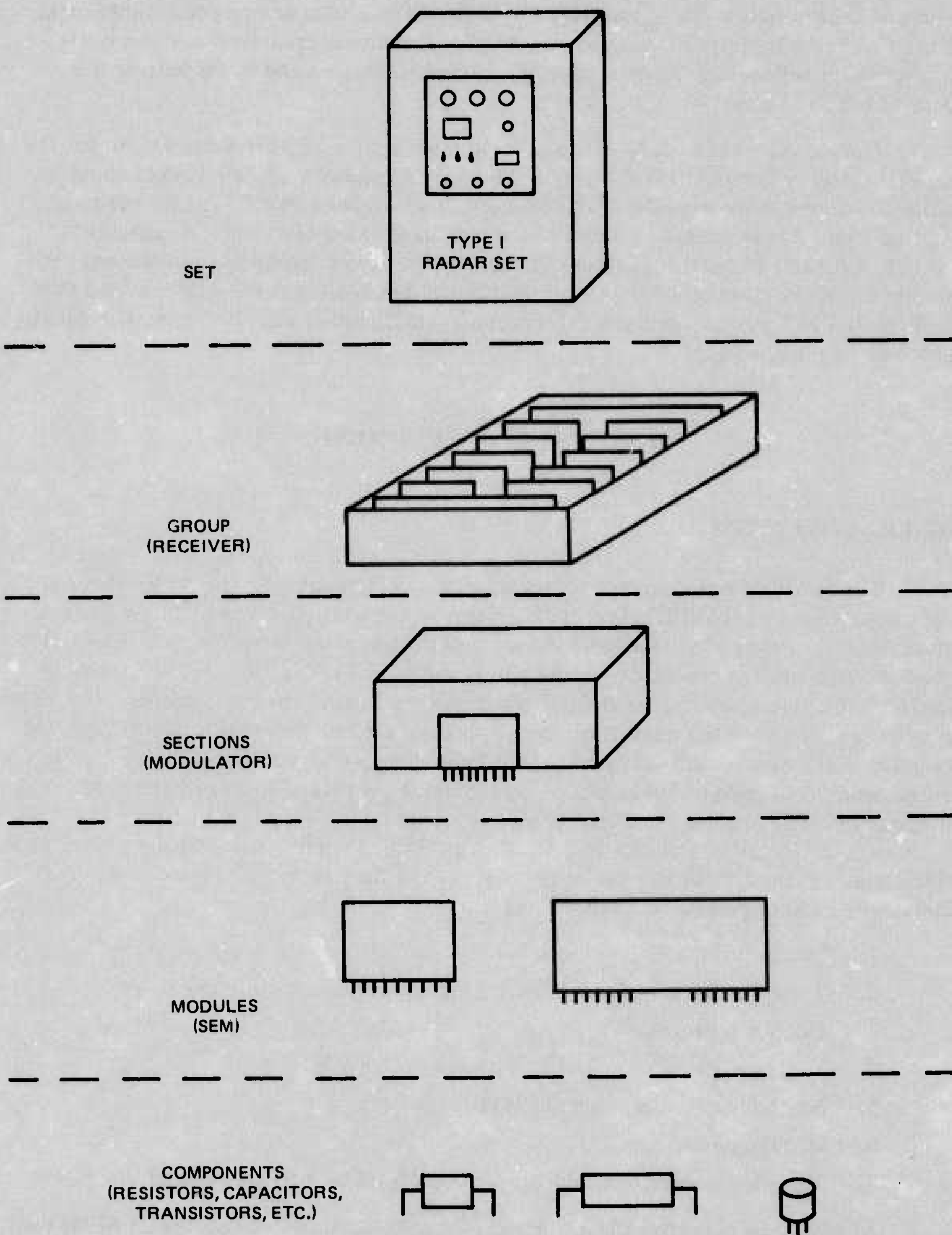

Figure 1. Levels of modularity.

The point made here is, that while we have three transmitters and two power supplies, they are not really unique sections as they have a high degree of commonality at a lower level of modularity, the SEM level. A glance at the listing of SEMs used in the four types, given in Appendix B, will show that very few SEMs are used in only one system.

By selecting certain of these groups, we can then assemble any of five different sets to satisfy the four type requirements. This is shown in graphical form in figure 2. One point not apparent in the discussion so far is that while only one timing and control component is shown, there is a difference between the Type I and Type II sets. The simpler requirements for such items as multiple PRFs for the Type II took fewer SEMs. This was accomplished by merely removing those modules which were not needed. The group frame, sockets and backplane wiring were left intact. This method achieves some cost savings through common construction and fewer parts and also leaves open the possibility of adding the increased capability at a later date.

Using the Type I system as a baseline, the degree of commonality can be expressed as the percentage of SEMs and components in the other sets that exist in the Type I. Doing this, we arrive at the following figures:

Type II 90 percent common with Type I,

Type III 100 percent common with Type I,

Type IV 81 percent common with Type I,

This percentage includes SEMs, microwave components, magnetrons, cabinets, control box, cabling, cooling system, mounting plates, cable connectors, delay lines, and card cages.

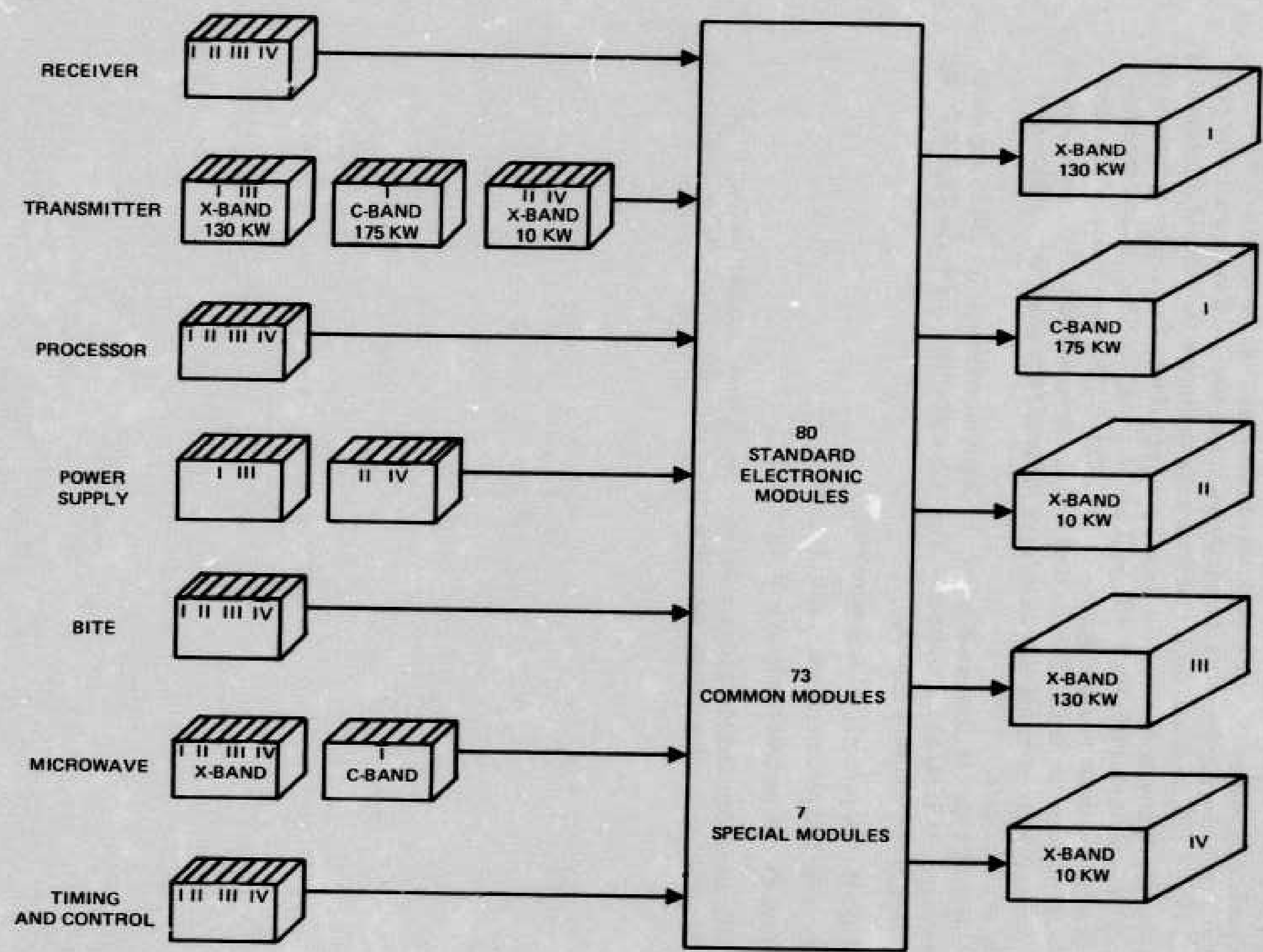

Figure 2. SEM-assembled radars.

DESIGN GOALS

In addition to the general parameter areas, considerations were given in the design of the 2175 modular radar to such items as possible application of military specifications, weight, reliability, life, operating environmental conditions, cooling, primary input power and a host of similar items. A listing of these goals for the Type I system is contained in Appendix C. This listing is representative of the other types with suitable corrections for such items as power, frequency, weight, and the like.

DETAILED DESCRIPTION OF EQUIPMENT

The following discussion of the equipment is limited to the block-diagram level. Figure 3 is a simplified overall block diagram of the Type I modular radar. Descriptions to the detailed circuit level will be included in the Test Phase Report which is scheduled for publication in December 1975. At that time, a complete drawing package will also be available.

SYSTEM POWER SUPPLY

A block diagram of the system power supply for the Type I, II, and III radars is shown in figure 4. The input power is 120 Vac, 3-phase, 60-or-400 Hz. The system can also be operated from 120 Vac, 1-phase 400 Hz without any change. The input power is first rectified and stored in a capacitor bank. The dc power for the control circuitry of the main power supply is developed in an auxilliary supply consisting of a free-running magnetic converter with two series regulators.

The main converter is a driven switching regulator. Its output is a pulse-width modulated rectangular wave. The power transformer develops the five different output voltages needed in the system. The output of the transformer is rectified and filtered and is then again regulated for use by the rest of the radar circuitry.

The output of the 5-volt rectifier/filter is used as a feedback for control of the main power converter. The 5-volt output is compared with an internal reference and an error signal is generated. The amplitude of the error signal is then compared with the amplitude of a 50 kHz saw-tooth signal. The crossover point of the saw tooth ramp and the error signal then generates a trigger which determines the width of the modulation signal (see figure 5). The modulation signal is then operated on in a digital circuit to produce the base-drive signal for the power converter. The output of the power converter is thus a series of alternating positive and negative rectangular pulses the width of which is determined by the output 5-volt level.

The remaining outputs tend to follow the 5-volt line. This results in regulation of between 3 and 5 percent for the remaining voltages. Additional regulation for system use is thus required. The dc-to-dc efficiency of the circuit is about 90 percent and, for the Types I, II, and III, the efficiency from input ac to output dc is about 80 percent.

The local oscillator requires very tight regulation and this unit was supplied with a remote-sense capability so that its voltage would be maintained at the point of use in the microwave section.

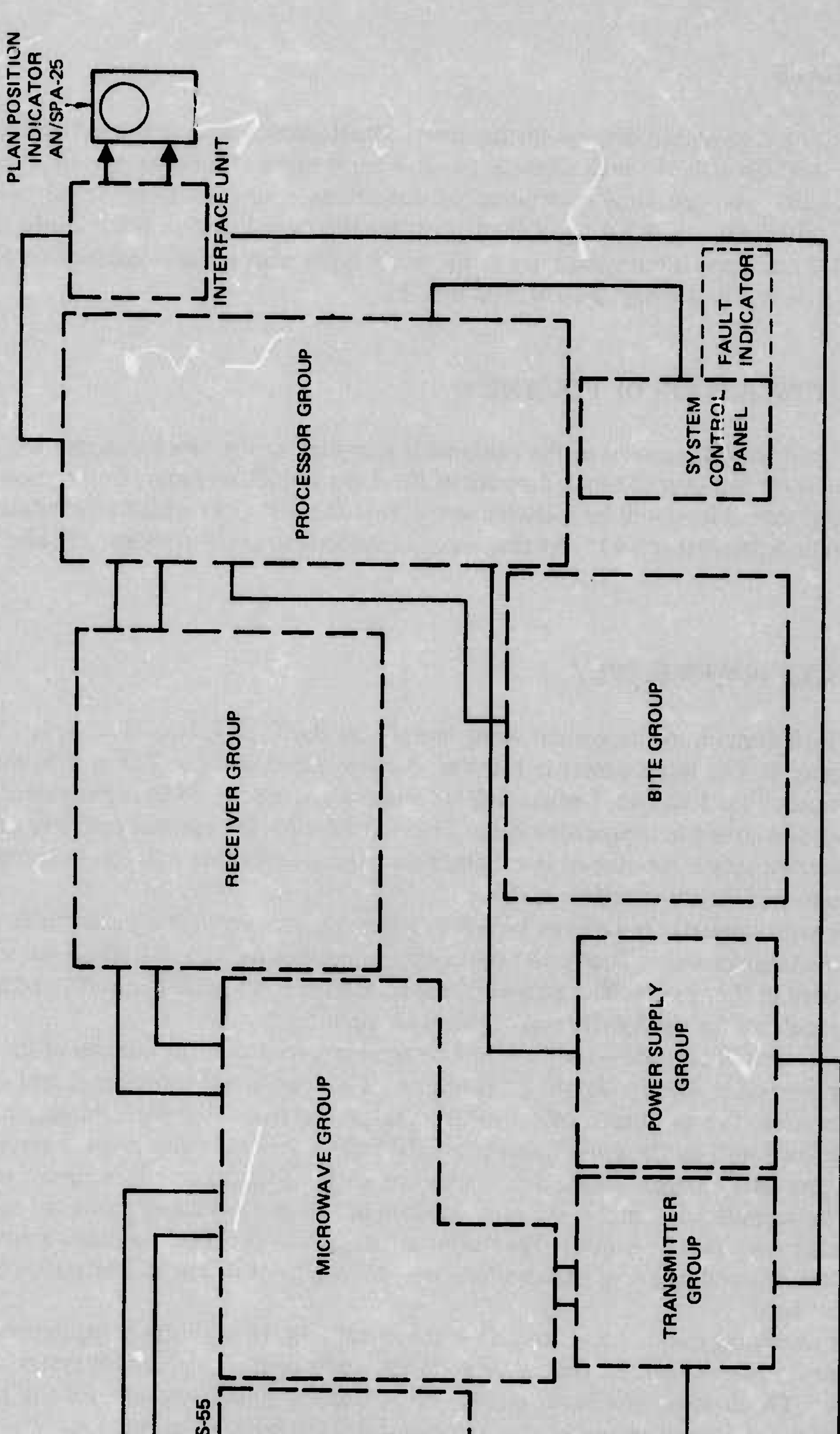

Figure 3. Simplified block diagram, Type I Modular Radar.

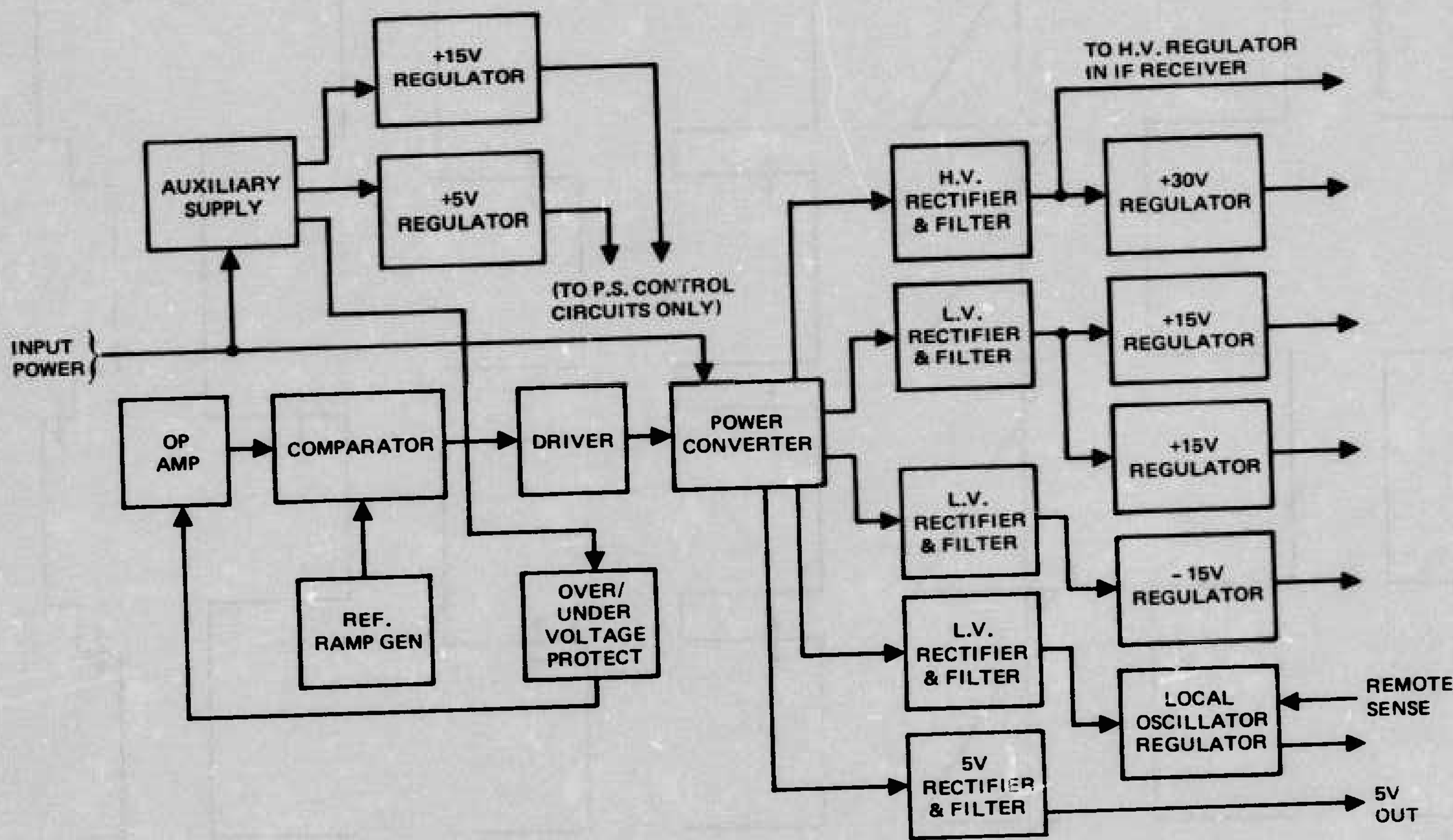

Figure 4. Power supply block diagram, Types I, II, and III.

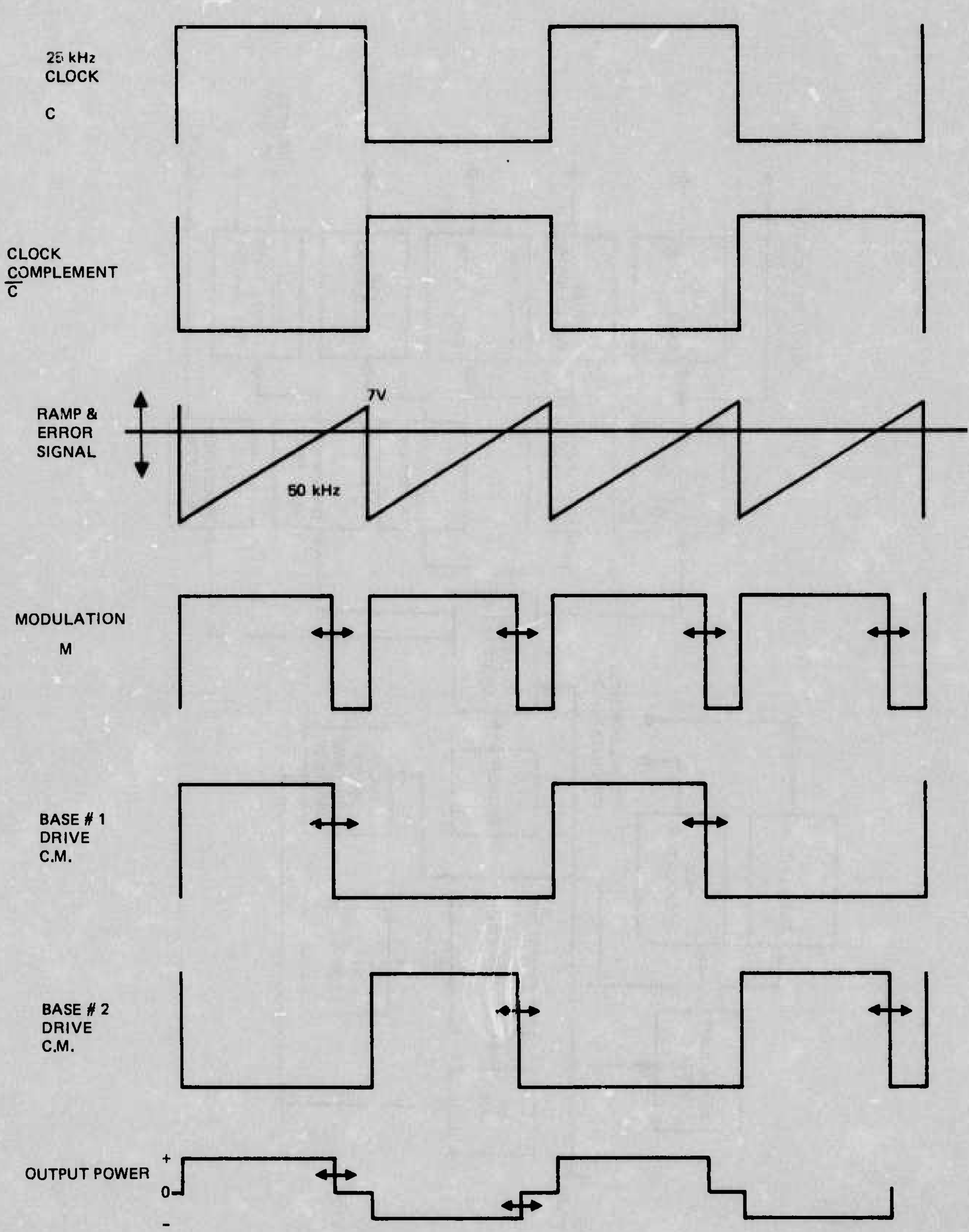

Figure 5. Regulator waveforms.

The Type IV system power supply operates in essentially the same manner. Fewer outputs are required for this simpler system and the input power is 28 Vdc and thus does not require the initial rectification and filtering, and, therefore, achieves a conversion efficiency of nearly 90 percent.

MODULATOR POWER SUPPLY

The modulator power supply operates in the same manner as the system power supply (see figure 6). The main differences are in the modulator voltage-select circuit, the output isolation, and the filament sense circuit. The modulator voltage select circuit is one which modifies the returned output sample so that the output high voltage for the magnetron is preadjusted to maintain the peak power when the pulsewidth is changed.

The filament sense circuit determines the rms value of the filament output and, since this is an ac output, converts it to dc and then compares it with the filament reference signal.

The output isolation LC filter shields the feedback signal from the modulation on the high voltage line when the magnetron turns on. To attempt regulation during this short peak demand would require an extremely complex design and would not achieve any improvement in the output pulse.

TRANSMITTER

The transmitter consists of the modulator and the magnetron power output tube. The modulator was designed in two modules, the charging network and the pulse-forming network (see figure 7). These two parts were separated for two reasons. First, to make them more easily managed for physical insertion into the SEM frame and second, to keep the high-voltage parts in their own module where proper attention could be given to any arcing problems.

The charging network consists of two charge-storage capacitors selected by means of a ceramic vacuum relay switch, depending upon the desired pulsewidth, and an SCR discharging circuit. The selected charge-storage capacitor is grounded by the SCRs when they are triggered by the main trigger from the timing and control circuit. This produces a pulse having a duration of about 5 microseconds with a peak amplitude of about 400 volts for the low-power (10kW) magnetron or about 900 volts for the high-power magnetrons. This pulse then goes to the pulse forming network module (PFN).

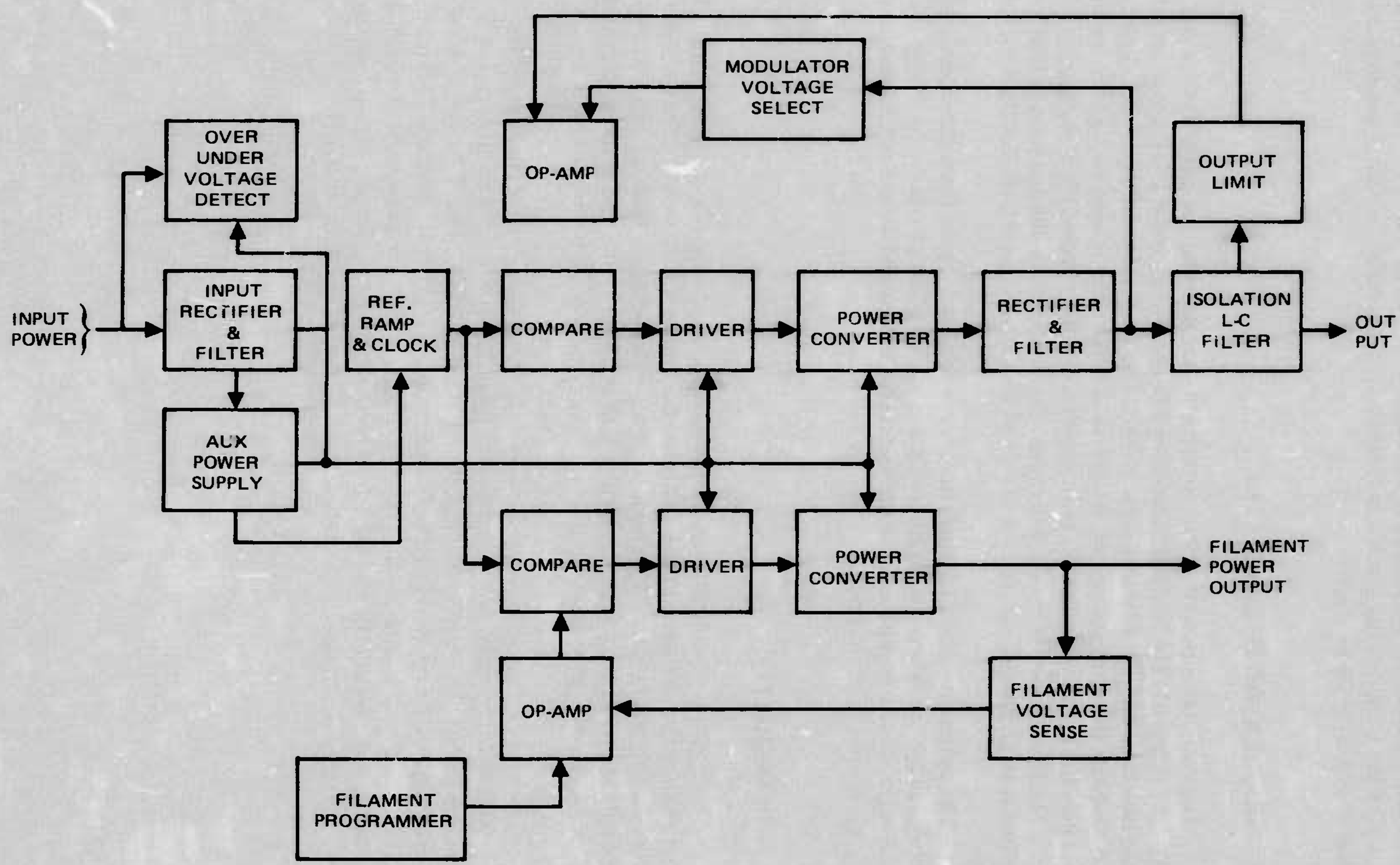

Figure 6. Modulator power supply block diagram.

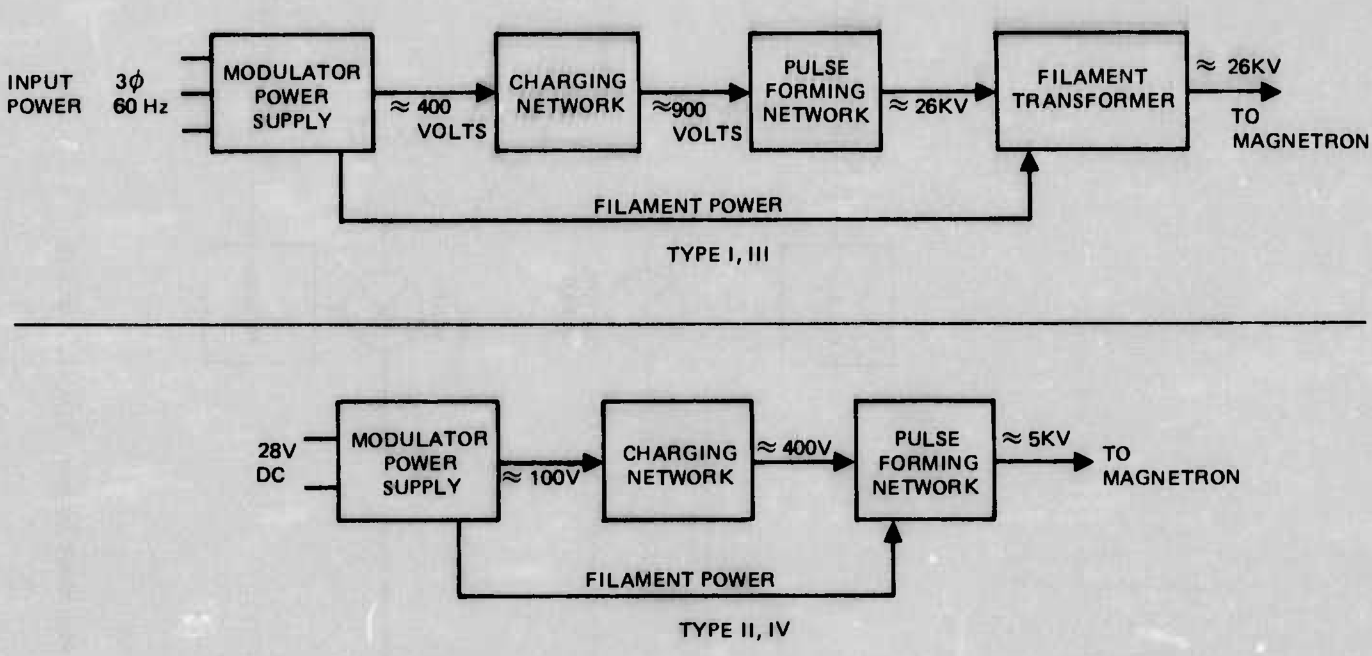

Figure 7. Modulator block diagrams.

The PFN has an input transformer which produces a pulse of about 3 kV for the low-power system or about 12 kV for the high-power system. The pulse then goes to a line-type PFN of selectable length, depending on desired pulselength, also switched by a ceramic vacuum relay. The output of the PFN is then further transformed up for use by the magnetron (about 5 kV for the low-power magnetron and up to 26 kV for the high-power C-band magnetron). The magnetron used in each case is a coaxial type. A QKH-1757 high-power magnetron is used at X-band, a SFD 373E high-power is used at C-band, and a L 5362 low-power is used at X-band.

MICROWAVE GROUP

The block diagram of the microwave group for the Types I, II, and III radars is shown in figure 8. This is a typical microwave design and only the special features will be

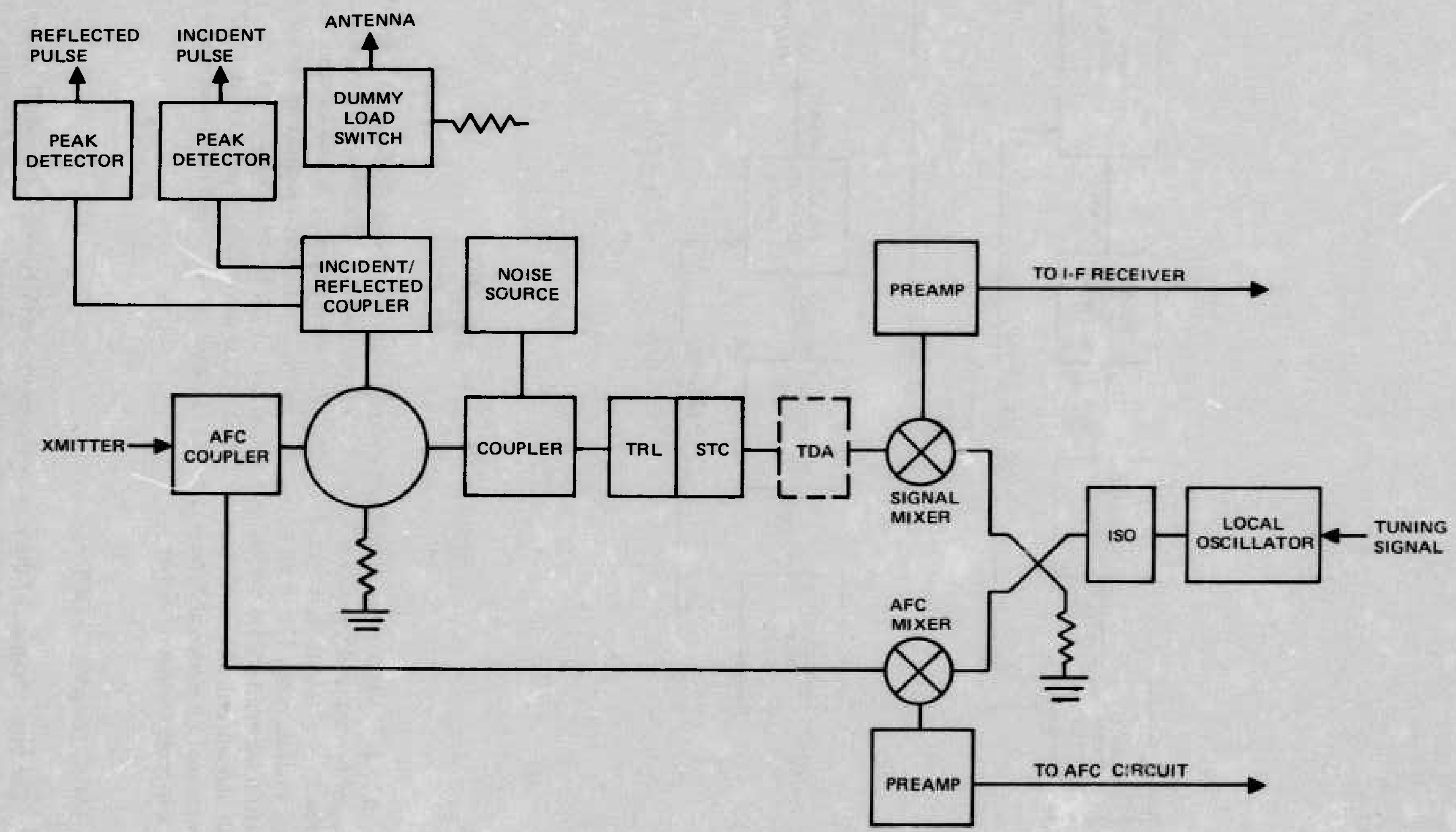

Figure 8. Microwave group block diagram, Types I, II, and III.

discussed. First, the transmitter output pulse is directed through the four-port circulator and then through an incident/reflected pulse coupler. This coupler develops a signal on the incident (transmitted) pulse which is sent to the built-in test equipment to verify the peak output power. The returned energy from the antenna is measured by the reflected-pulse peak detector and is a measure of the (VSWR) voltage standing wave ratio. A VSWR of 2 to 1 represents a return of about 10 percent of the transmitted energy and indicates a problem in the waveguide run, the rotary coupler, or in the antenna itself. This combination will not cause damage to the transmitter, but is indicative of a problem that should be corrected. Under these conditions, the BITE circuit will indicate a marginal condition on the control panel. If the reflected pulse indicates a VSWR of 4 to 1 on four successive pulses (about 35 percent reflected power), the Transmitter Protection Circuit will shut down the transmitter and BITE will indicate a failure on the control panel. A VSWR of this magnitude would result in magnetron failure in a short period of time.

Provision is made for inserting periodically a noise signal of known magnitude into the receiving portion by means of the noise source and its coupler in the microwave group. This signal is pulsed during the period of time just preceding the main bang and is then picked up at the output of the receiver and compared with a reference in the BITE group. Any significant deviation of this output signal indicates a problem in the receiver or microwave receiver group and the BITE will search for the area of failure (see Built-In Test Equipment).

The STC (Sensitivity Time Control) diode attenuator following the TRL (Transmit/Receive Limiter) produces the STC attenuation. It has a range of 40 dB.

The dotted block labeled TDA is a space left on the microwave group for future inclusion of a tunnel diode amplifier if an improved noise figure is necessary. The main reason it is not included at this time is that the 10-dB noise figure appears adequate and the reliability of the tunnel diode amplifiers is low and they are susceptible to burnout.

The mixer is of a standard single balanced design, coupled with an i-f preamplifier having a gain of about 20 dB.

The output of the solid-state local oscillator is split by a magic tee and equal signals are sent to the signal and afc mixers. The i-f center frequency in both mixers is 60 MHz.

The afc mixer generates an i-f signal by mixing the transmitted pulse with the output of the local oscillator. This signal is then sent to the receiver group for processing. The afc action will be discussed under the receiver section of this document.

One last item should be mentioned in respect to the microwave group and that is its physical construction. The placement of the microwave components on the SEM frame was found not to be practicable. The desire to maintain the module replacement philosophy resulted in an unique design for this group. All of the microwave components are attached individually to a base plate called a manifold. This manifold provides rigid mounting for the components and necessary interconnections by means of waveguide couplings on the back (see figures 9 and 10). If a failure should occur in any microwave component, only the failed part needs to be removed. No unsupported waveguide sections are left dangling. This type of construction should greatly reduce repair time in this area.

Unfortunately, the size constraint for the Type IV system does not allow the manifold approach and a more conventional construction is employed. The Type IV system, however, is designed to be serviced at a repair facility so the extra time for repair may not be too important.

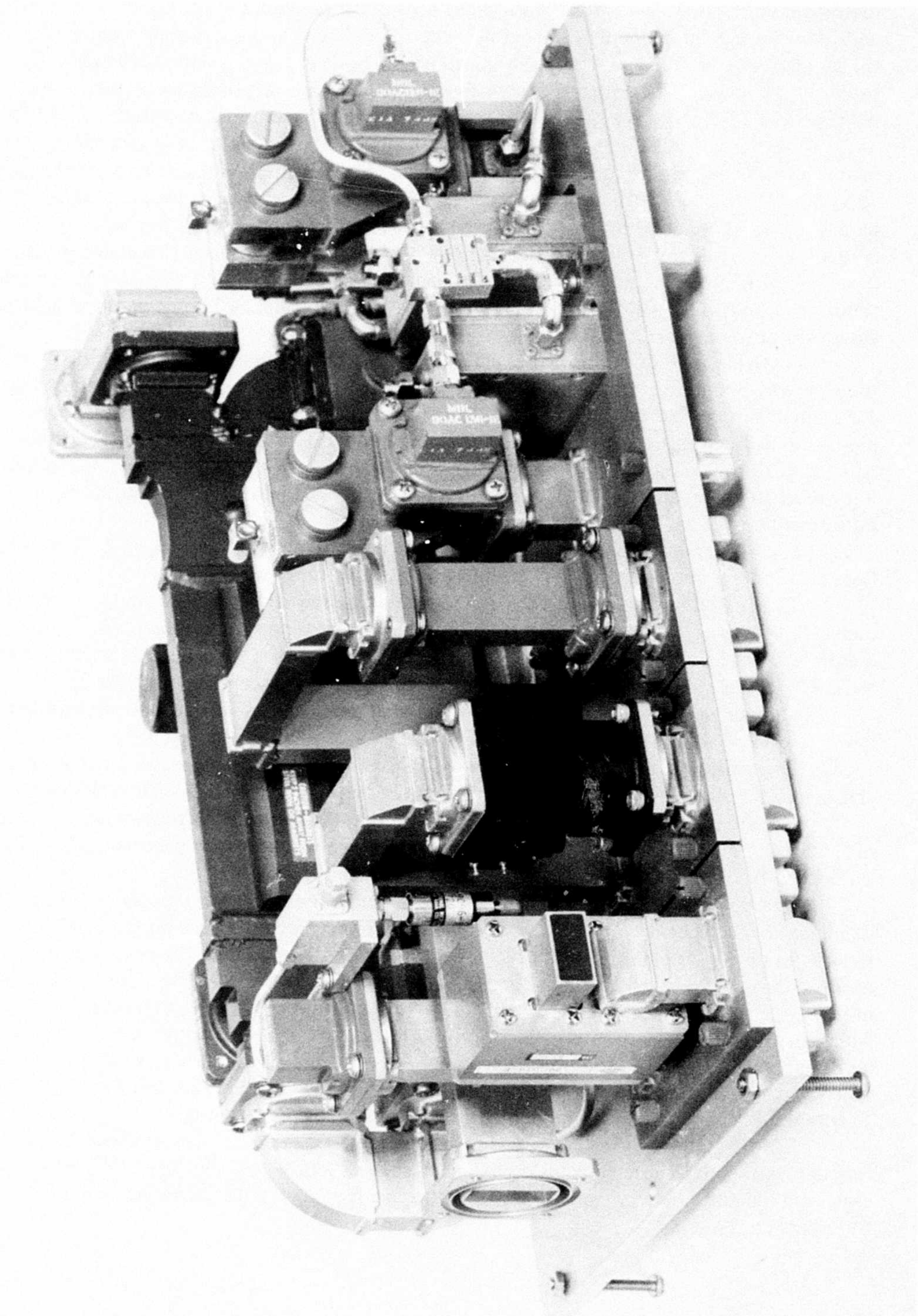

Figure 9. Microwave group component mounting arrangement.

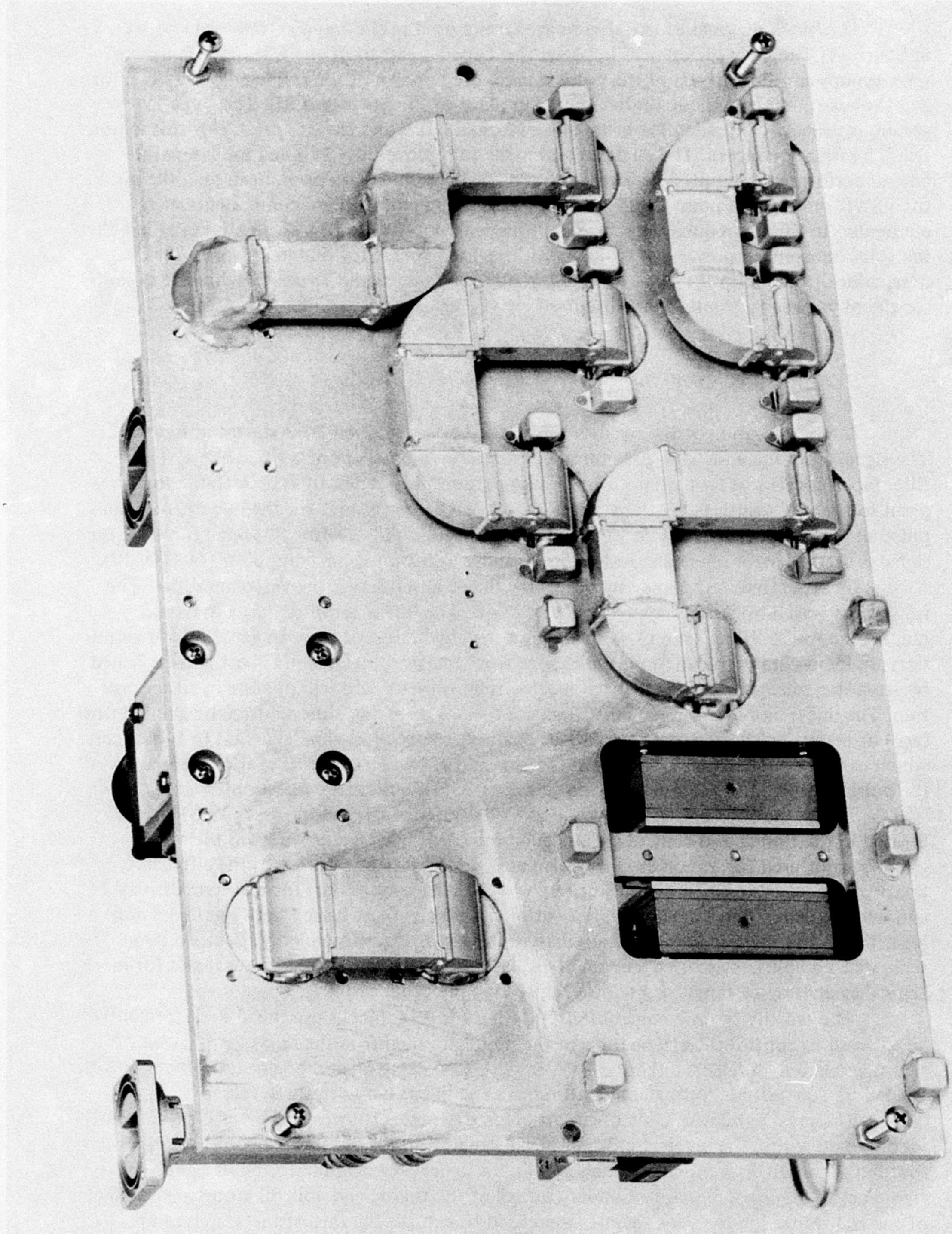

Figure 10. Rear view of microwave group.

The block diagram of the Microwave Group used in the Type IV radar can be seen in figure 11. The main differences between the Type IV and the Type I, II, and III microwave groups are the removal of the noise source, the removal of the reflected-pulse detector, and the use of a ferrite-diode limiter (FDL) in place of the gas tube TRL. The Type IV system is primarily intended for installation in small boats and riverine craft. For this reason size is a primary concern. The decision was made to remove the BITE and use a separate box to perform any required maintenance at a staging point. With no built-in test, the need for VSWR sensing and noise-signal insertion was eliminated, so there components were eliminated to further reduce the size. Since the peak power was 10 kW, a FDL could handle the total transmitted power and its inherent long-life expectancy dictated its use. The remainder of the group for Type IV is essentially the same as the Types I, II, and III except for the physical construction just discussed.

RECEIVER GROUP

A block diagram of the receiver group for Types I, II, and III is shown in figure 12. The signal from the wideband pre-amplifier passes through a bandpass filter block. The filter block eonsists of two separate 3-pole assynchronously tuned filters selectable to correspond to the pulsewidth being transmitted. A 1.2-MHz filter is used for the one-microsecond pulse and a 12-MHz filter is used for the 100-nanosecond pulse. After this band limiting, the signal is used to drive simultaneously a linear and a logarithmic post amplifier (LOG AMP).

Incorporated in the same module with the i-f amplifiers is the video amplifier. The gain of the post amplifiers is approximately 75 dB. The linear amplifier has a dynamic range of about 25 dB and the LOG AMP has a dynamic range of close to 60 dB. Both amplifiers are identical in eonstruction, the change from linear to logarithmic being accomplished by strapping selected pins on the backpanel wiring. Either board will operate in either position. The linear amplifier has a front panel control for selecting either automatic gain control (agc) or manual gain control. Following both amplifiers is a fast-time-constant (FTC) circuit which can be switched on or off from the front panel. The FTC circuit is also affected by the pulsewidth so that the time constant is about 25 percent of the pulse time.

The output of the LOG AMP is sent to the video-clutter-suppressor (VCS) circuit located in the timing and control group. The processed signal, returned from the VCS circuit, is buffered for use on auxiliary displays. A video-select switch permits either the linear or processed logarithmic output to go to the buffer amplifiers for the main display and one auxiliary. There are four video outputs. Two can be switched between linear and logarithmic and the remaining two auxiliary outputs are logarithmic only. Because two separate i-f amplifiers are used, the main display can be changed to the linear mode for more critical evaluation of target size without upsetting the other displays.

The sensitivity time control (STC) timing and STC blocks produced the exponential signal used to control the attenuation of the diode attenuator in the microwave group. A front-panel control selects either an R^{-3}, R^{-4}, or R^{-5} delay characteristic. Another control, labeled STC amplitude, provides a continuous adjustment between these values.

The local oscillator, control-circuit block diagram is shown in figure 13. This circuit is contained within the receiver group. The i-f signal from the afc mixer and preamplifier is first fed to an afc discriminator which develops a signal proportional to the i-f signal frequency. This signal is sampled under control of the timing and control group at the time of the transmitted pulse. This signal is then used to control the rate of the search ramp

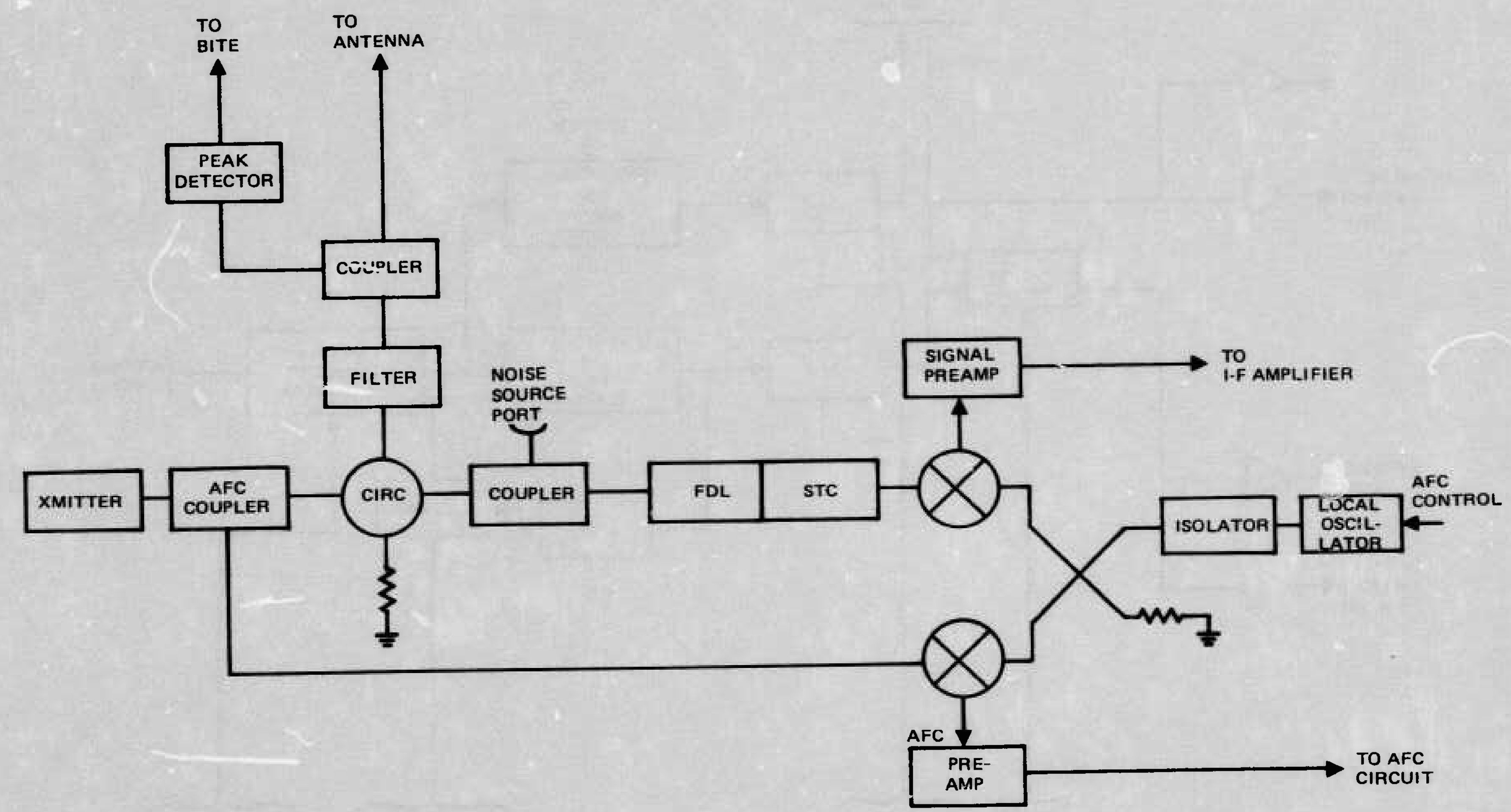

Figure 11. Microwave group block diagram, Type IV.

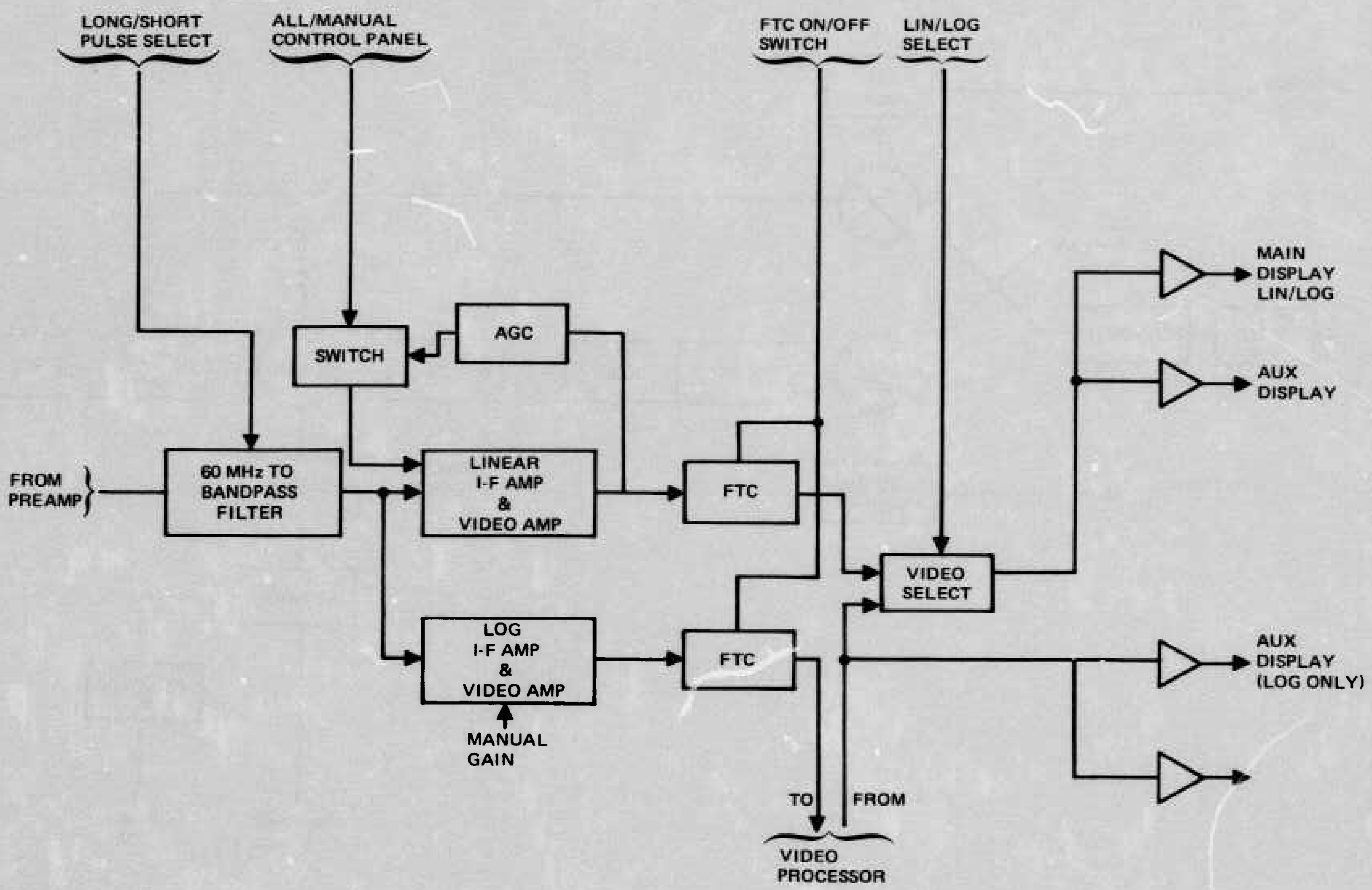

Figure 12. Recciver group block diagram, Types I, II, and III.

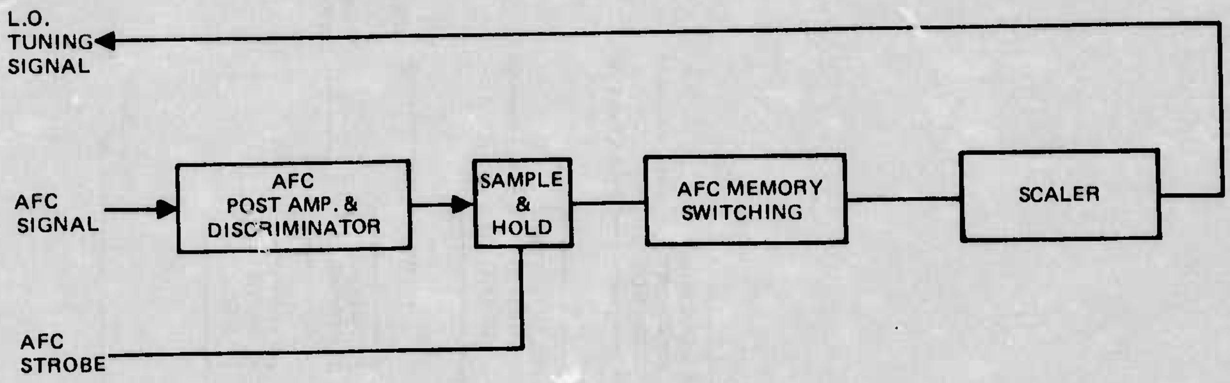

Figure 13. Local oscillator, control-circuit block diagram.

generated in the afc memory/switching block. In the event of an off-frequency condition, a search ramp is generated which causes the local oscillator (LO) to sweep through its range approximately every 600 milliseconds. As the LO approaches the correct value, the rate of change is slowed. Upon reaching the correct value, the sweep ramp is held constant. A correction signal is obtained at each pulse and holds the LO to within approximately 100 kHz. Since the mixer i-f is related on a Hertz-to-Hertz basis to the transmitter, the magnetron frequency drift is followed to within 100 kHz, or well inside the bandpass requirements. The scaler block changes the 8-volt sweep out of the afc memory/switching block to the 10-to-48 volt range needed by the Gunn diode in the LO.

Another item which should be mentioned is not shown on the block diagram. This is the development of a 90-dB dynamic range logarithmic i-f amplifier. NAVSECNORDIV suggested that a dynamic range of between 55 and 60 dB was insufficient so a new design was undertaken by NAFI engineers. This design has been proven successful in demonstrating a dynamic range of 90 dB using the breadboard model. Lack of time and funding did not permit the completion of a finished module for the 2175 systems. Any follow-on systems, however, will be able to use this advantage without further design.

The Type IV receiver is the same as the one just discussed except that only one i-f amplifier is used and the LIN/LOG amplifier (similar to the one just described) is biased at a slightly different point so as to produce a linear output during the first zero to 10 dB out of the noise, depending upon the gain setting, and to be logarithmic after that point. Since this is essentially a logarithmic amplifier, no automatic gain is incorporated. This system is intended for use on small boats where it is unlikely that more than one display would be desired. For this reason, only one output is provided.

TIMING AND CONTROL GROUP

The heart of the timing and control group is the timing-pulse generator (see fig. 14). A 12.288-MHz clock generates the primary frequency from which all other timing is derived. The 12.288-MHz clock pulses the timing counter (16-bit counter) which

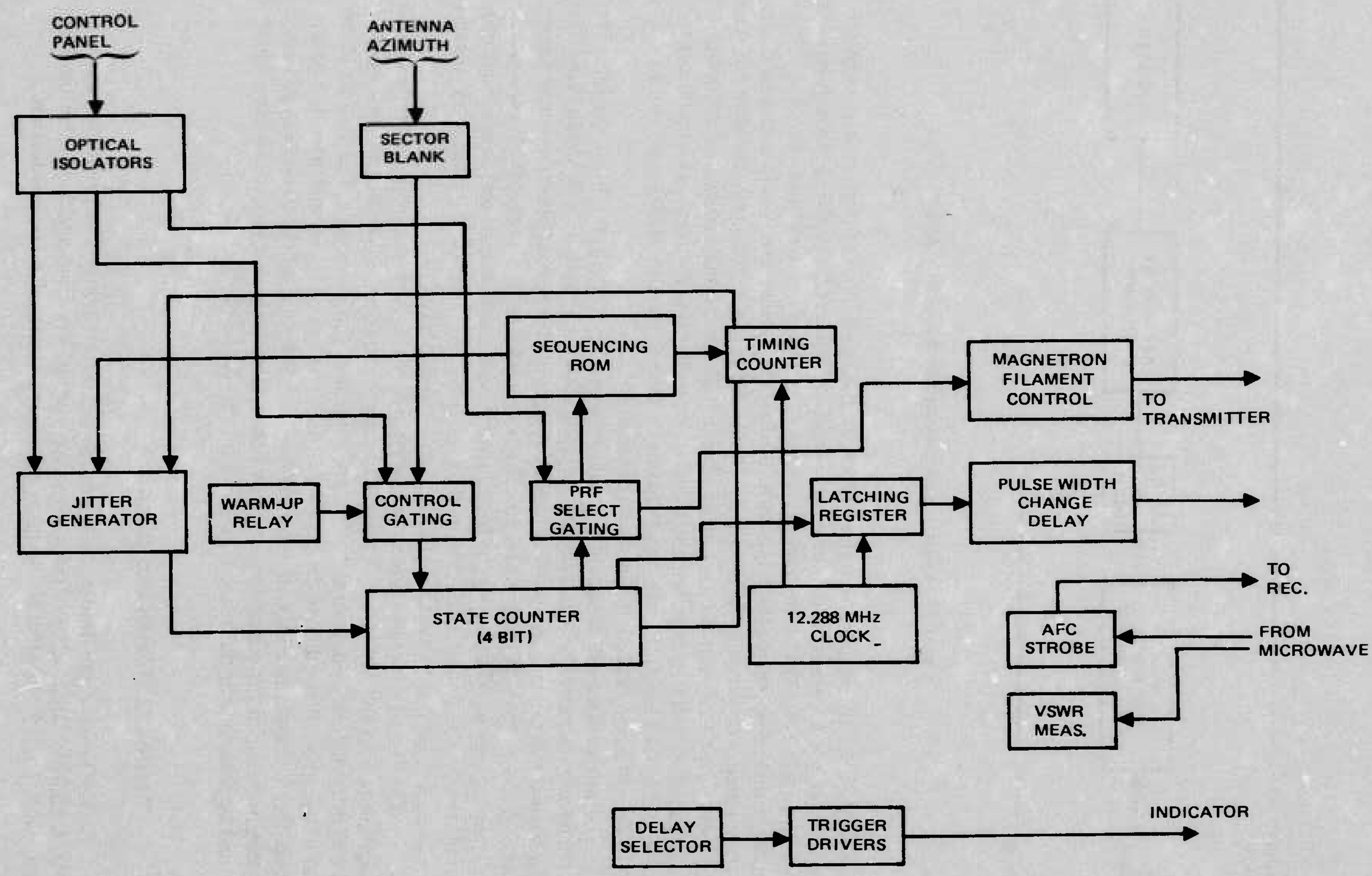

Figure 14. Timing and control group block diagram.

up-counts until it reaches a terminal binary count condition (all "1"s). Upon reaching the terminal count, the timing counter outputs a count into the 4-bit state counter, increasing its count by one. The 4-bit number on the state counter is then read into the sequencing read-only memory (ROM) through the pulse-repetition frequency (prf) select gating block. The output of the ROM then jam-sets a new number, depending upon the binary number on the state counter and the ROM program, into the timing counter. The next time period is then determined by how long it takes the 12.288-MHz clock to count up the timing counter again to its terminal value. The various waveforms are shown in figures 15 and 16.

The sequence is started when both the state counter and the timing counter reach their terminal counts (all "1"s). When this occurs, the state counter is preset to a designated state (0100 for the Types I, II, and III radars and to 1000 for the Type IV radar). These timing sequences are shown in figures 14 and 15. To obtain different timing intervals, all that is necessary is to replace the sequencing ROM with one having a different program. This is a 1A SEM module replacement.

The different prf intervals are determined by the digital logic in the prf-select gating block. This circuit takes the output of the state counter and transforms it into the correct code for the prf interval. The code conversion for the different pulse-repetition frequencies is controlled by the setting of the prf control on the front panel.

All signals from the local and remote-control panels are optically isolated to provide good noise immunity and to remove any ground-loop problems between the remote panel and the radar set.

The sector-blanking control is also located in this group. Its inputs are from the control-panel selector switch and the azimuth signal from the antenna. The sector-blanking signal goes to the control-gating circuit which inhibits the modulator trigger during the time sector blanking is desired. Also feeding the control gating-block is a warm-up delay signal that prevents any modulator triggers until after a 5-minute initial warm-up of the magnetron filament. (Note that this is an initial turn-on delay only.) The time to switch from Standby or Silent mode to Operate mode is the lock-up time of the LO and is estimated to be about 300 milliseconds (600 milliseconds would be maximum).

A magnetron filament control is provided to adjust the power into the filament corresponding to the average power output of the magnetron which, in turn, depends upon the prf and pulsewidth.

The pulsewidth-changed delay is a protection circuit which will not allow the modulator trigger to pass while the pulsewidth control is being changed. This is to protect the contacts of the vacuum relays in the charging and pulse-forming networks.

An internally set delay selector is also included in this group to provide a selectable delay of from zero to 1.28 microseconds in 16 increments, each of 80 nanoseconds, to synchronize the indicator trigger with all miscellaneous delays in the system. Such things as modulator, magnetron, and waveguide delays will vary from one installation to another and can be adjusted on site.

The last block in this group is the jitter generator. When enabled by a front-panel control, the jitter generator takes over the function of the timing counter for the last period of time in the sequence. It operates in the same fashion as the timing counter (counting up to a terminal count from a preset number) except that the preset number is determined almost at random by a pseudo-random number generator. The pseudo-random generator repeats the pattern about every 5 weeks (at 750 pps). Limits are placed on the range of the pseudo-random numbers so that deviations from the average will not exceed ±11 percent. However, smaller deviations may be programmed. In the event the jitter generator fails to put out a signal, the timing counter will initiate a pulse that will produce another transmitter output although the prf will be lower than that shown by front-panel settings.

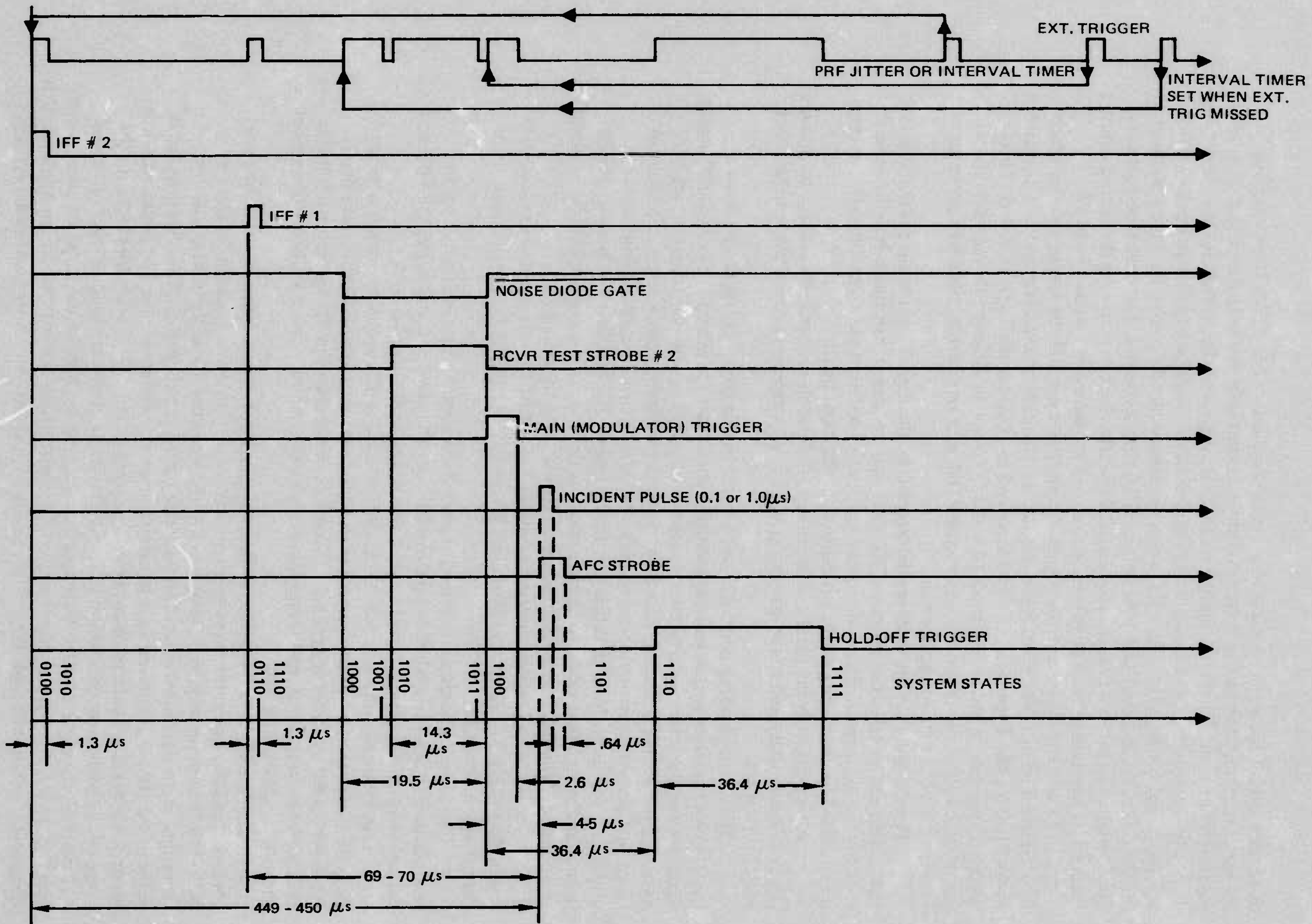

Figure 15. Timing diagram for Modular Radar, Types I, II, and III.

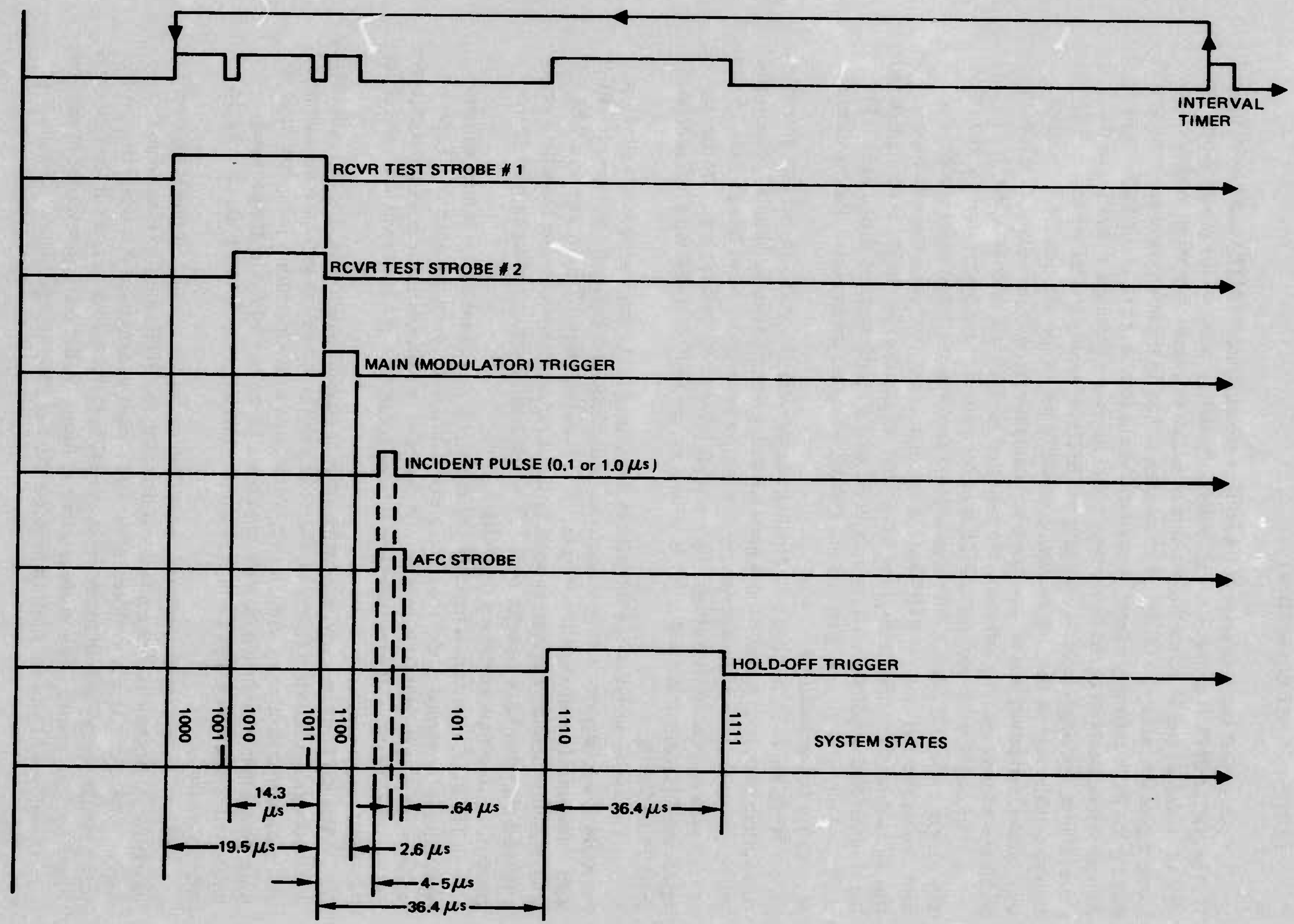

Figure 16. Timing diagram for Modular Radar, Type IV.

BUILT-IN TEST EQUIPMENT

A simplified block diagram of the built-in test equipment (BITE) is shown in figure 17. The goal of BITE is to automatically detect any failure in any of the groups which comprise the radar set and to define the location of failure to a small number of modules. The ultimate goal is to achieve a MTTR of 15 minutes or less. In the interests of economy and of keeping the BITE relatively simple, it was decided not to attempt to locate the fault to an individual module. Most of the repair time would be used in getting a technician to the radar cabinet, opening it up, and exercising the BITE to identify the failure source. The time to actually replace the plug-in module would be only a few seconds. So, a figure of six modules, maximum, was chosen as a group containing a potential failure. This is not a restrictive number and, in most cases, the indicated modules will be four or less.

The overall operation of the BITE is under control of a program stored in the ROM. This program selects the test points in an ordered sequence. Each test point is compared with a value also stored in the ROM and the microprocessor then performs a decision-making calculation to determine if the test point is acceptable. The BITE, as configured for the Modular Radar system, has a capacity of 96 analog signals and 256 digital signals. For the Type I set, only 32 analog signals and 160 digital signals are measured, leaving plenty of room for future additions.

While the BITE is capable of handling signals from –5 volts to +5 volts, an area of over-voltage indication is desired, as a nominal analog might be exceeded by 50 percent and still be operational. To allow a range, the nominal value was selected as being from –3.5 volts to +3.5 volts and the analog voltages are preconditioned to fall in this range. The digital signals are TTL-compatible and a "0" is defined as zero to +0.75 volts and a "1" is defined as +2.75 to 5 volts.

The entire operation is controlled by the project and comparative values stored in the ROM so a totally new test procedure can be implemented merely by replacing the ROM with a new one. It is also worth noting that the Modular Radar BITE Group uses a 7 by 1/4K Memory module. The system could easily be expanded by replacing this with a newly produced chip that has a capacity of full 7K without requiring any other changes to the group other than reprogramming the ROM.

The BITE operation is based on the assumption that hard-device failures will predominate. In its normal mode, the BITE is insensitive to transient malfunctions. There is, however, an intermittent-fault-detect mode that may be utilized manually by the equipment operator. In this mode, the transient insensitivity is removed and faults will be displayed on the digital readout meter.

The BITE failure analysis is patterned after conventional troubleshooting procedures. A flow diagram is shown in figure 18. Each test point is accessed in sequence and compared with data stored in memory. Analog data is evaluated with a maximum/minimum window while digital data is evaluated on a go-no-go basis. In the normal mode, the good-bad judgement is based on a large number of samples taken from each test point (usually 16 individual tests).

If no failures are encountered, the system cycles through all test points approximately every 20 seconds. When a failure is detected, the BITE enters a failure-analysis routine. The first action is a self-test of the BITE itself to determine if it is indicating a failure elsewhere when the fault really lies in the BITE. If the self-test is good, it then executes a failure-tracing routine. This mode is shown in figure 19. Beginning at level one in the fault tree, the BITE will proceed through by levels. No test point is dependent on any point of

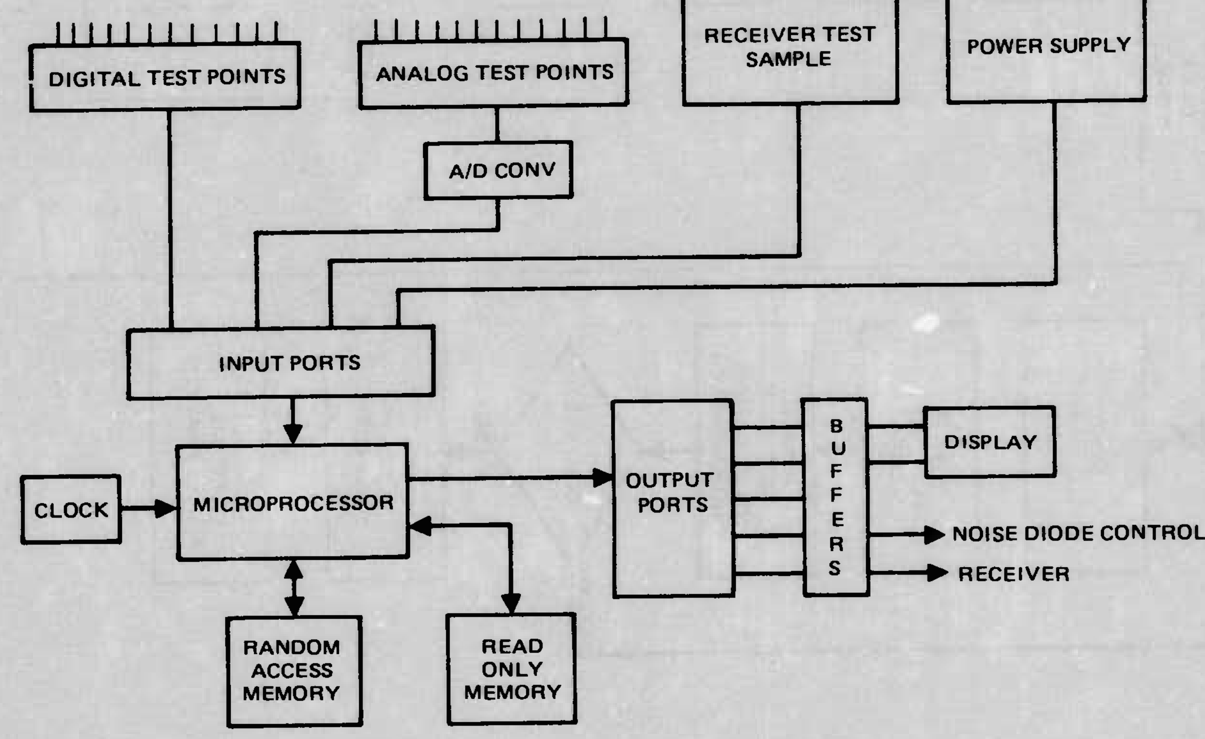

Figure 17. BITE block diagram.

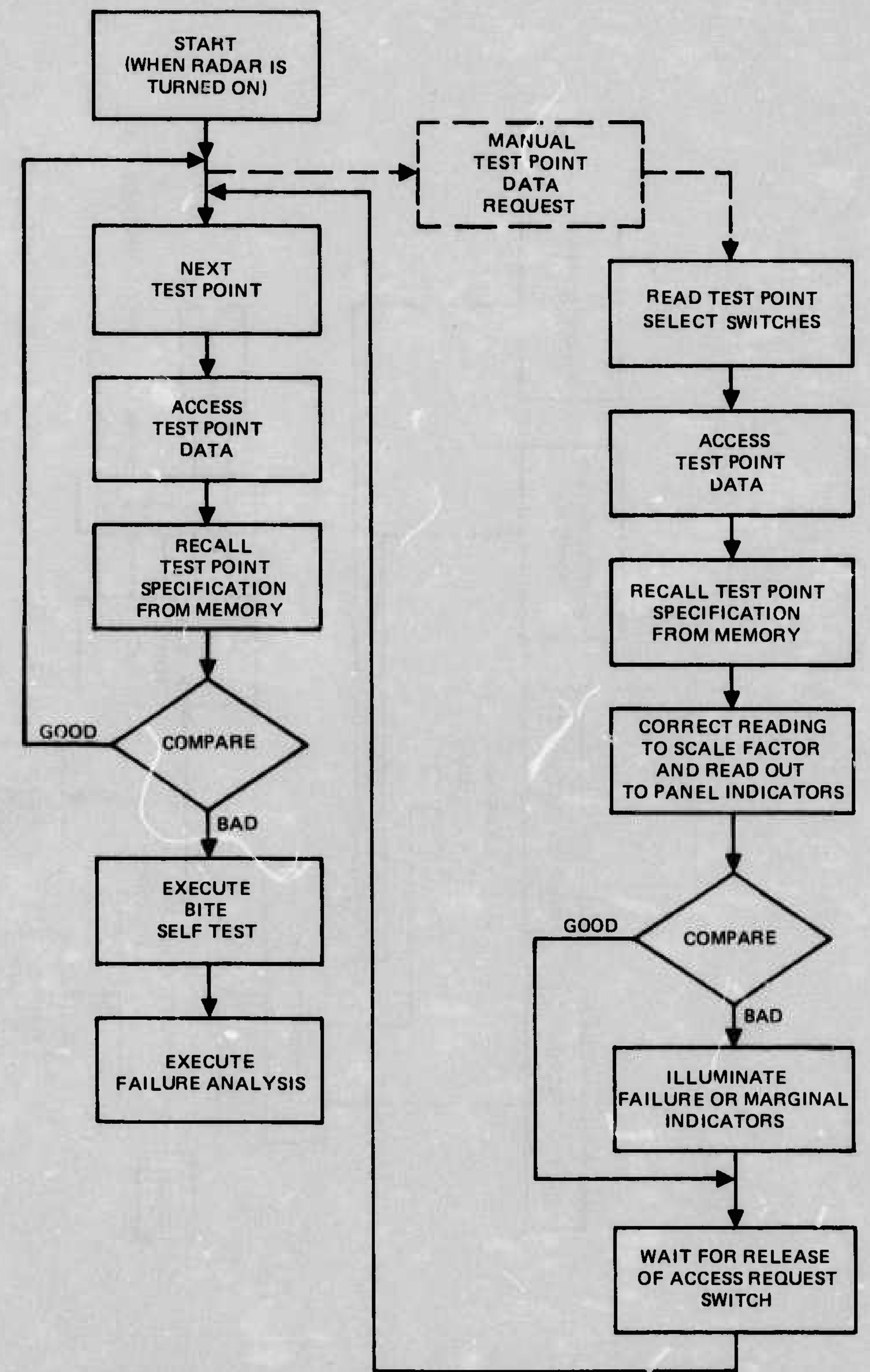

Figure 18. BITE operation flow diagram.

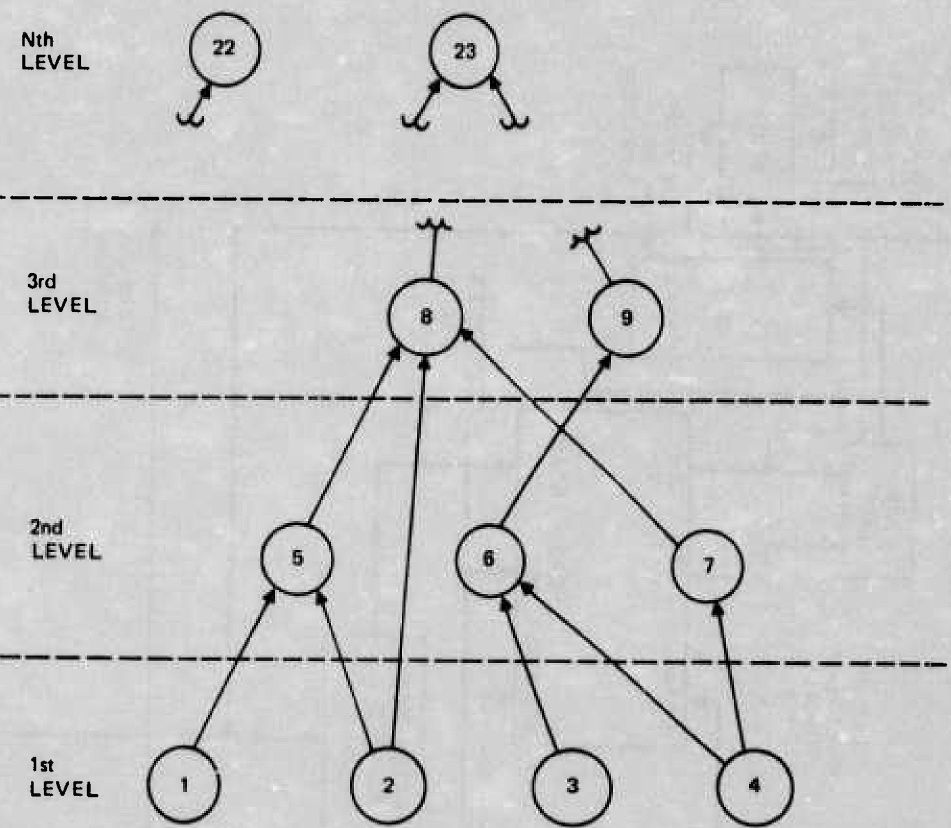

Figure 19. BITE fault-tree diagram.

its own level or on any higher numbered level. The first test point found in error is read out on the digital indicator and either the marginal or failure lamp is lit. In the event the test point that initially caused entry into the fault analysis routine is again reached and no failure is detected, then an intermittent condition is assumed and the BITE reverts to the search mode.

When a failure is indicated, the operator will refer to a listing of test points on a card attached to the equipment. For each test point, there will be a list of module replacements to be performed. The list will give the most likely candidate first and the least likely candidate last.

In the event the operator desires to perform his own diagnostic routine, he can select any test point, by means of a front-panel control, and read out the voltage at that test point. To perform a manual test, the operator is required to hold down a spring-return switch. This will insure the automatic mode of failure search resumes when the operator has walked away from the radar cabinet.

G.O.N. VIDEO PROCESSOR TYPES I AND IV

The block diagram of the video processor circuit is shown in figure 20. The analog video signal from the LOG amplifier is first converted into an 8-bit digital signal by the analog-to-digital (A/D) converter. This conversion is performed each 1.14 microseconds. The digital number corresponding to the signal amplitude is then stored in a nine-word by

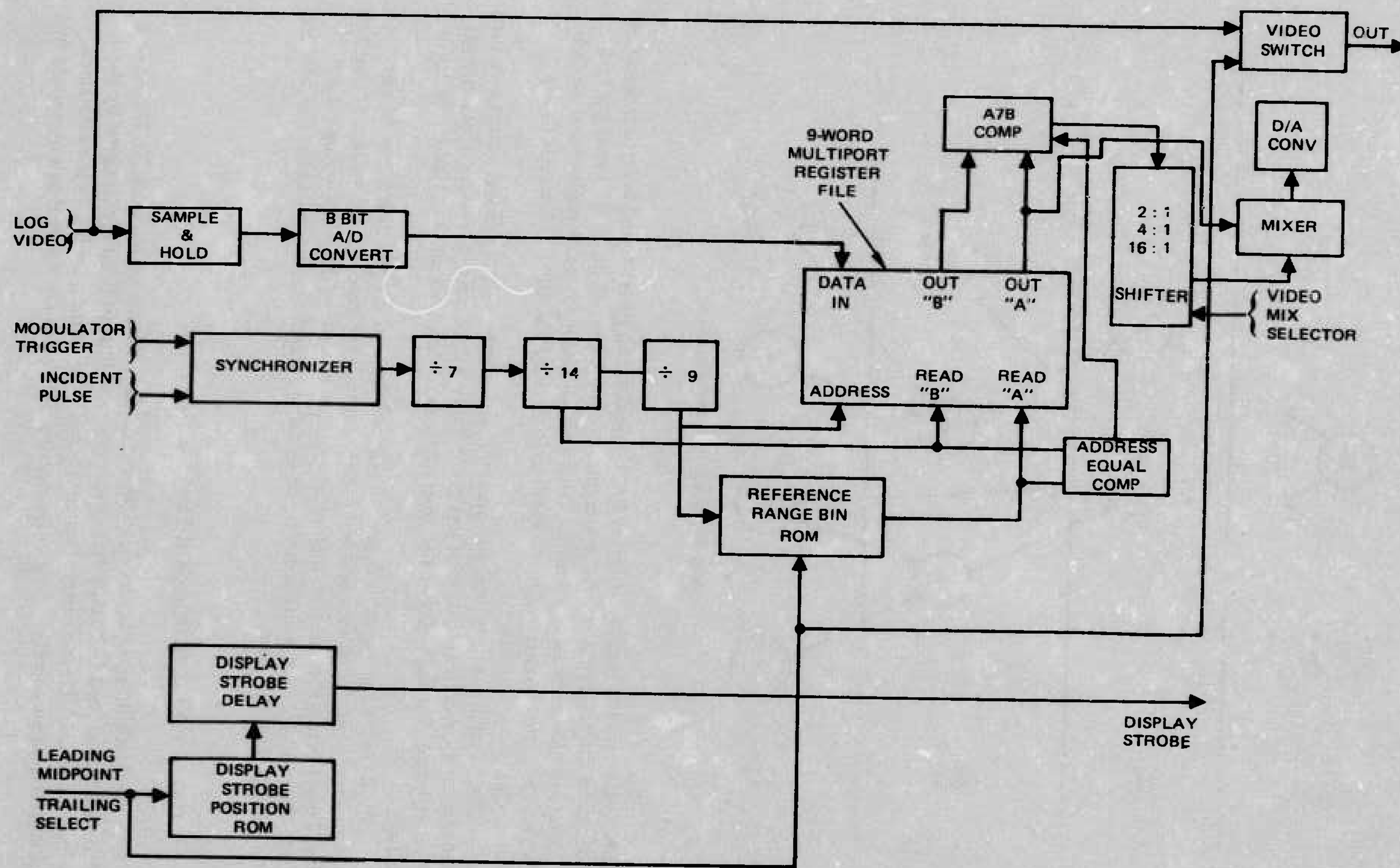

Figure 20. G.O.N. (VCS) processor block diagram, Types I and IV.

eight-bit memory called the multiport register file. Each successive conversion is stored in a separate address in the file until all nine-word positions become full. The data in the file at this point represents the past history of the signal divided into nine time cells. Next, a comparison is made between the selected time cell (output A) and all the rest of the cells (output B). Output A, the selected time cell, can be the first data in (leading-edge reference), time cell 5 can be the midpoint reference or the last data in (trailing-point reference). Each of the other outputs is sequentially compared to the selected reference. If the selected time cell is greater than any of the other cells, it is allowed to pass on to the D/A converter and the analog signal is sent on to the video output.

This sequence takes place as follows: Assume the address locations in the multiport register are numbered one through nine. Also assume that the file is filled starting with position one and ending with position nine. Consider the leading-edge time cell as the reference. After nine time periods, the file is full as shown in figure 21. The leading edge of the time block is in cell one (T_0). If this cell were greater than any of the others, it would be transferred out. However, it is apparent from the figure that the data in cell three (T_2) is greater, so no output is produced. The next A/D converter signal now replaces the data in cell one. This becomes a new data-bank time reference as shown in figure 22. The reference cell is now cell two, which corresponds to the new T_0 point. The old T_2 is now T_1' and is still the largest so there is no output. The next conversion stores in cell two (fig. 23). The reference block becomes cell three (time T_0) which is now the leading edge of the time frame under consideration. Since this cell contains the signal with the maximum amplitude, it will be allowed to process through.

Since this operation will remove all signals except the largest one in any nine-cell time frame, it is apparent that if several real targets are close enough to be included in the time frame, only one will be displayed. To overcome this complete removal, a video mix is allowed where either all the data can be allowed to pass through (no removal) or the greatest signal can be allowed through at full amplitude with all the others reduced by a factor of one-quarter or one-sixteenth their normal amplitude. This will allow the largest targets to be displayed at full brilliance and everything else at corresponding reduced intensity. The utility of this circuit will be evaluated during the test phase.

When the leading-edge reference is chosen, it is necessary to have all nine cells filled by subsequent time data before a comparison can be made. This means 9 times 1.14 microseconds will have passed before the information is allowed to pass on to the display. To correct this shift from real time, a delay is provided for the display trigger. This delay is a function of which cell is used for the reference, being six time-cell periods for a mid-point reference and one time-cell period for a trailing-edge reference. This delay is provided by the display strobe-position ROM and display strobe-delay counter.

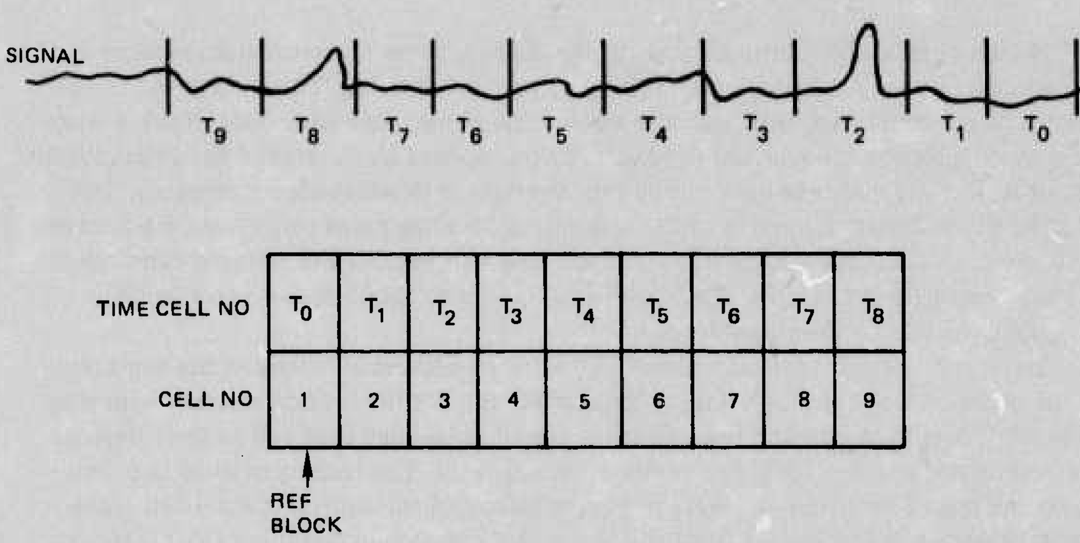

Figure 21. State of filled multiport register.

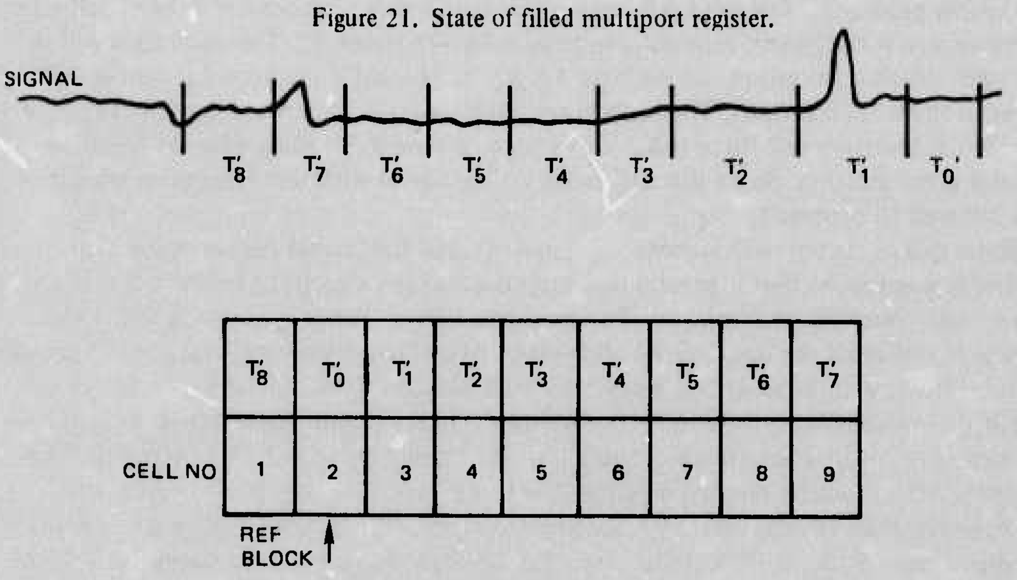

Figure 22. Updated multiport register data point contents.

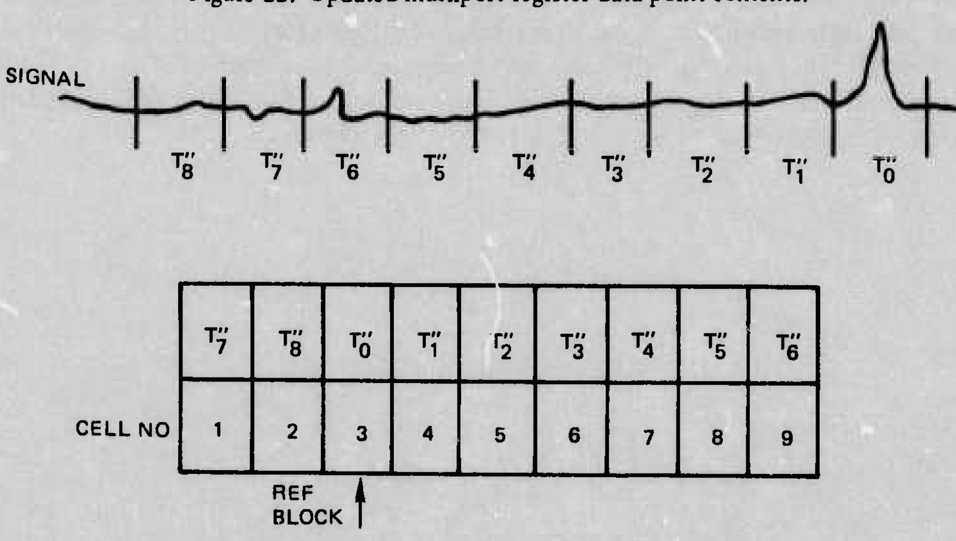

Figure 23. Second update of multiport register.

SEM COMMONALITY

As one of the major objectives of the Modular Radar Project was to prove the feasibility of utilizing common modules across the family, some measure of achievement needs to be reported upon.

There are two areas in which a significant advance has been obtained. The first is at the group level. The program will demonstrate, during the next fiscal year, that radar sets can be assembled to fill the four type requirements using only 11 group-level building blocks. If these five radars (two for Type I) were to be separately designed and manufactured, each set would have its own unique set of groups. Simple arithmetic shows that five sets times seven groups amounts to 35 groups, each requiring its own logistic support and repair manuals. The same operational performance can be obtained with the modular family using less than one-third the number of groups.

Another measure of commonality can be obtained by inspection of the SEM-level modules used to fabricate the groups. In many cases, the same SEM type (3-letter code) is used in several different groups. An alphabetical listing of all of the SEMs used is contained in Appendix B and is further broken down by group usage in Appendix C.

It should be kept in mind that only seven of the 80 modules shown in Appendix B and Appendix C are of such a specific nature that their use will probably be limited to radar systems. All the rest have utility in other electronic systems.

A point worth mentioning is in regard to the qualification of these modules by NAFI and NADCrane for inclusion into the SEM listings. The cost of qualification has been estimated to be about $15,000 per design. This figure was clearly outside the scope and funding of the 2175 project. NAVSEA 0652 has been very interested in this project and is now moving to transfer it from 6.2 into 6.3 funding. Since it has committed itself, NAVELEX has given verbal indications that it will undertake the funding for qualification of new SEM designs as required. This should help to make the SEM method more acceptable in future designs as many new circuit functions will then be available.

SYSTEM OPERATION

PERFORMANCE PREDICTIONS

Comparisons of the operating performance can be found in table 3. These ranges were calculated using a computer program and are useful only for mathematical comparisons for the specific parameters inserted into the project. Such things as weather conditions and ducting phenomena were not included. These are not actual operating performances and as such are indicative only of possible performance comparison. These calculations were necessary for design information to ensure at least equivalent performance between the new and existing designs.

Actual performance comparisons will be made during the test phase (see Test Plan).

TABLE 3. COMPARISONS OF OPERATING PERFORMANCE.

	AN/SPS-10	1-C	AN/SPS-55	1-X	AN/SPS-53	IV-X_1	LN-66	IV-X_2	AN/BPS-15	IV-X_{sub}
P(Kw)	285	170	130	130	35	10	10	10	35	10
Horiz Beam	1.5°	1.5°	1.5°	1.5°	1.6°	1.5°	1.56°	1.56°	3°	3°
Ant RPM	16	16	16	16	15	15	22	22	15	15
Bandwidth	1 & 5	1.2 & 12	1.2 & 10	1.2 & 12	4 & 12	1.2 & 12	14	1.2 & 12	4 & 12	1.2 & 12
PRF	650	4K & 1K	750 & 2.5K	4K & 1K	750 & 1.5K	4K & 1K	800 & 2.5K	4K & 1K	750 & 1.5K	4K & 1K
Pulse Width	0.25 & 1.3	0.1 & 1.0	0.12 & 1.0	0.1 & 1.0	0.1 & 1.0	0.1 & 1.0	0.05 & 0.5	0.1 & 1.0	0.1 & 0.5	0.1 & 1.0
Ant Gain	32	32	31	31	29	31	28	28	29.5	29.5
T_x Freq	5.5	5.5	9.5	9.5	9.4	9.4	9.4	9.4	8.8	9.0
NF	14	10	10	10	11	10	11	10	10	10
P_{avg}(w)	240	170	97	130	26.3	10	4	10	13.1	10
Range (nm)	15.72	17.51	10.71	11.11	4.81	5.93	2.56	4.09	5.37	5.43
Change (nm)	—	1.79	—	0.4	—	1.12	—	1.53	—	0.06

PRELIMINARY TEST PLAN FOR MODULAR RADAR SYSTEM

GENERAL

This test and evaluation will be the final phase of the 2175 Modular Radar Project. It will show the operational capability of the total system including parameter measurement, evaluation of all control settings, and comparison with typical surface-search radars used today.

PURPOSE

To evaluate the design as to the suitability for the surface-search functions as delineated in the four surface-search radar types listed by NAVSEC.

OBJECTIVE

To ascertain how close the equipment meets the design goals and to compare performance with the AN/SPS-10, the AN/SPS-55 and the LN-66 radars. To determine the flexibility of parameter modification, to investigate ease of repair, and to identify any areas needing improvement. Reliability and environmental testing will not be performed on this equipment.

PERFORMANCE BASELINE

The baseline measurements should verify the major performance parameters of the radar. The following parameter tests are essential for baseline data:

Transmitter:

Frequency, Tuning Range, Power Output, Pulsewidth, PRF, Pulse Shape, Spectrum.

Receiver:

Noise Figure, Image Rejection, Bandwidth, STC, LOG & LIN Video Accuracy, MDS, Minimum Range, Long & Short Pulse Response, AFC Accuracy, LO Stability, FTC.

Detection Test:

Blip Scan Ratio versus Range On test targets of various sizes. STC, FTC, and GON in clutter environments.

Output Data (Display Compatability)

Both the AN/SPA-25 and AN/SPA-8 Indicator Groups are available for use during these tests. Although most system testing will use the AN/SPA-25, verification of the compatability of the AN/SPA-8 is also planned.

IFF, Blanking, and Indicator Triggers:

These output trigger pulses will be recorded to verify specified requirements of timing, rise time, level, pulsewidth, and jitter. They will be loaded as required.

Controls/Indicator Evaluation:

During the course of testing, the operability of the various controls and indicators will be noted.

Operability for Normal Use:

Observations and a review will be made of the ease and efficiency with which the operator can carry out his tasks in start-up, operations, and shut-down of equipment. Among points to be considered will be delays, decision times, availability of adequate information, logical sequences, potential for errors, amount of eye and hand motion, and rapidity of feedback data. This review will be made in coordination with engineering tests during actual operation.

Recoverability:

Observations and a review will be made of the ease and efficiency with which a full-capability condition can be restored subsequent to equipment faults or operator-induced errors. In addition, the effect of combinations of inappropriate operator actions on equipment performance will be reviewed, it being reasonable to assume that such non-normal control sequences will occur. This review will also be made in coordination with engineering tests during operation.
The BITE will be evaluated by having a card removed and noting how quickly a technician can locate the fault using the BITE indicators. Times required to locate faults in a total of 30 tries conducted at random intervals will be recorded. The test is to include at least one simulated failure in the microwave section and one simulated failure in the magnetron.

Safety:

First, a check-list inspection will be conducted of potential hazards to the equipment from operators and maintainers, and to the operators from the equipment, including such points as interlocks and warning displays between the control cabinets, power supply, and antenna. Subsequently, observations will be made during equipment operation. Finally, combinations of inappropriate procedures and actions will be reviewed for potential hazards.

Comparative Tests:

In addition to the baseline tests, comparative performance tests will be made with the AN/SPS-10, AN/SPS-55 and LN-66 to determine operational acceptability. Included in these tests will be comparisons of the following:

Minimum and maximum range,

Ship and aircraft detectability of targets-of-opportunity,

Performance in clutter,

Range resolution,

Maintainability,

Input power requirements,

Operability (human factors), and

Compatability with existing AN/SPS-10, AN/SPS-55, and LN-66 antennas and pedestals.

TEST PLAN SCHEDULE

Figure 24 presents the schedule for the evaluation phase.

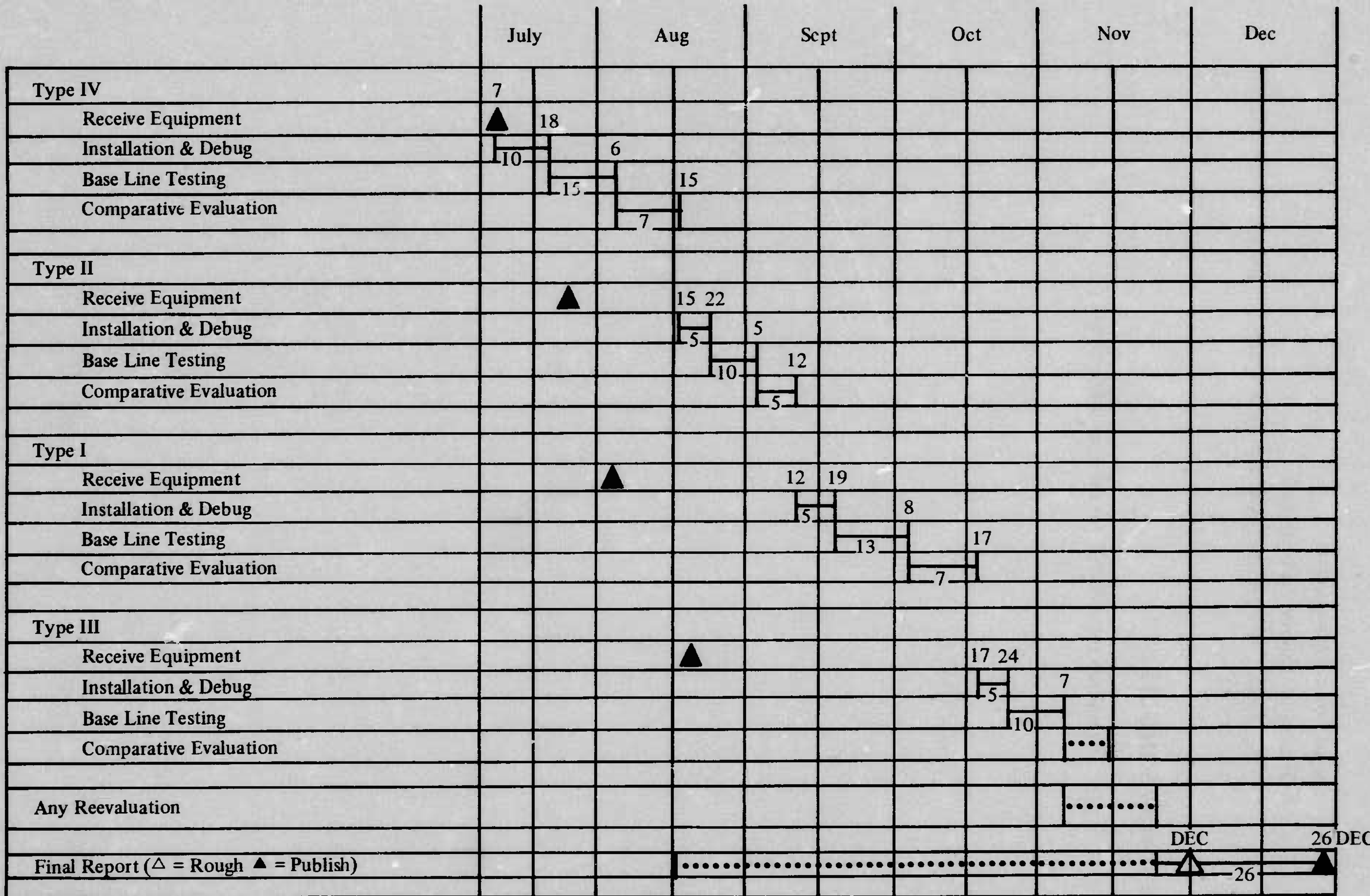

Figure 24. Evaluation phase schedule.

LIFE-CYCLE COSTS

One of the prime objectives of the 2175 Modular Radar Program was to show potential two-for-one savings in Life Cycle Costs (LCC). The LCC for the 2175 radar were developed by EG&G Washington Analytical Services Inc.[4] NAVSEA Code 652 is the cognizant agency for the report of these findings and requests for additional information not contained in this technical document should be directed to that organization.

The report itemizes all cost areas except manning (cost of operating personnel). This cost item was excluded because it was felt that it would be the same regardless of the design of a particular radar. The report shows that if the Type I C-band, the Type II, and Type IV, X-band systems only were used (these represent current requirements), the average cost-per-year, based on a 15-year useful life, would amount to $5,300. A separate calculation of only the Types II and IV yielded the same LCC ($5,300/set/year). This means that the Type I, C-band set, when included in the family, has a life cycle cost in the family of $5,300 per year.

The only surface-search radar found with complete life-cycle data was the AN/SPS-10 and its Mods. A report prepared by ARINC Research Corporation gave a complete breakdown of the life-cycle costs for 987 AN/SPS-10 radars.[5]. The data, as calculated, were for a 10-year expected life. Since the LCC estimate[4] for the modular radar was based on a more realistic 15-year expected life, a correction was needed in order to compare the LCC estimate with the AN/SPS-10 figures. To do this, development, production, installation, and disposal costs were kept constant as one-time costs while maintenance, technical and management, and modification costs were multiplied by 1.5 to reflect the 15-year period. This calculation is shown in table 4. The estimate for the modular radar was made using 1975 dollars by multiplying the AN/SPS-10 costs by 1.66, generally taken to be the escalation in costs from 1965 to 1975,[6] we arrive at a comparative 1975 figure.

The result of the calculation shows that the AN/SPS-10, if designed and used today, would cost $10,747 per year per set. When this is compared to the estimated cost per year of the Modular Type I C-band set of $5,300 per year per set, an improvement of 2.03 to 1 is shown in favor of the modular set.

As a check on the validity of these calculations, comparisons were made between the modular radar costs and maintenance costs published by NAVSHIPS[7] and NAVSECNORDIV.[8] Average maintenance cost of 409 reporting AN/SPS-10s were shown to be $4,374 per year per set based on 1972 dollars.

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4. Life-Cycle Cost Estimate for Surface-Search Radar utilizing the SEM Concept, EG&G Washington Analytical Services Inc., May 1975.
5. Cost Evaluation and Cost Estimating for Shipboard Electronic Equipment, ARINC Research Corporation, April 1967.
6. Naval Sea Systems Command NAVSEA Research Paper 11R4-74, Economic Escalation Index for Defense Electronic Systems, 6 November 1974.
7. Naval Ship Systems Command, NAVSHIPS Engineering Bulletin 843, 11 December 1972.
8. NAVSECNORDIV Report 14-73, 2D/3D Radar Equipments MCDS and CASREPT, RM and A Indices for Surface Ships, 9 November 1973.

TABLE 4. LIFE-CYCLE COSTS (CORRECTED).

AN/SPS-10 DATA	$ Per Yr	$ Per 10 Yrs	$ per 15 Yrs
Development	37.43	374.30	374.30
Procurement	1523.50	15235.00	15235.00
Installation	1532.00	15320.00	15320.00
Maintenance	3682.34	36823.40	55235.10
Mgmt & Tech Service	150.28	1502.80	2254.20
Modifications	24.44	244.40	366.60
Disposal	832.78	8327.80	8327.80
			97113.00

Cost per yr per set = \$6474.2 (1966 Dollars)

Cost Today = \$6474.2 X 1.66 = \$10747 (1975 \$)

$$\text{LCC Saving} = \frac{\$10747}{\$5300} = 2.03/1.0$$

These are actual reported costs. The ARINC report[5] shows an average cost of \$3,682 per year per set (based on 1975 dollars). It should be noted that the ARINC data on the AN/SPS-10 represent low estimates. This can also be seen by noting that ARINC lists the acquisition cost of each AN/SPS-10 as \$15,235. A check, made with the Federal Stock Number Book, revealed that the purchase prices for the AN/SPS-10 series varied from \$17,530 to \$52,000. These costs are shown in table 5.

TABLE 5. PROCUREMENT COSTS FOR AN/SPS-10 RADARS.

Set	Price	Quantity in Use (1972)
AN/SPS-10	$47,500	42
AN/SPS-10B	47,500	215
AN/SPS-10C	27,750	50
AN/SPS-10D	17,530	83
AN/SPS-10E	52,000	33
AN/SPS-10F	29,000	85
AN/SPS-10G	44,900	(not available)

The reason for the wide spread of costs has not been determined. However, a look over the list would lead to a conservative estimate of cost of \$30,000, at least, if these sets were to be procured today. The ARINC figure, when multiplied by the 1.66 escalation factor, yields a figure of \$25,290. Again, this figure can be observed to be on the low side.

Comparison of the Modular Radar Type IV with the currently utilized LN-66 was not possible as LCC figures for the LN-66 were not available. The LN-66 is a commercial radar intended for non-military use and manufactured by the Canadian Marconi Company. While it is reported to be a good performing radar, its reliability under battle conditions is wholly unknown. In addition, and perhaps more important, is the fact that the Navy owns no rights to this design and should the Canadian Marconi Company stop production, the Navy would have to add yet another design to its inventory for future requirements. Being at the mercy of a foreign manufacturer is not an attractive prospect. There is also concern in the matter of obtaining repair parts for a model that might be discontinued. The estimated production cost for the Modular Type IV system of $28,100 per set seems high when compared with the $8,000-to-$10,000 cost for the commercial LN-66 radar, but consideration needs to be given to the fact we are not comparing apples with apples. The Modular Radar is a full military-environment designed radar having its own repair equipment. The MTBF is nearly twice the commercial figure and the MTTR is about one half.

A feel for what it means to go from a commercial design to a military design can be obtained by comparing the present cost for the Italian SMA-3 commercial radar with a verbal estimate made by Dynell Corporation for an up-graded American design of the same radar for the PHM-class ships. The commercial version sells for about $20,000 while the Dynell estimate for the version using American components was between $25,000 and $30,000, plus any start up costs. This estimate is not a firm commitment from Dynell, but can be used for comparative purposes.

It is interesting to note, that the Modular Type IV set would perform almost as well as the SMA-3 and would only use about one third the prime power.

The previously mentioned ARINC report[5] evaluated the actual costs of many different electronic systems and generated several empirical formulas for estimating future costs. The formula for radar systems was given as:

$$l_n\,(\text{cost}) = 1.876 + (146.5/\text{MTBF}) + 0.0924\,(\text{MTTR}) + 0.0145\,(\text{percent utilization}).$$

This formula is shown in graphic form in figure 25. Points corresponding to the average of all AN/SPS-10s and the very best one (AN/SPS-10F) are shown. The dotted lines shows one-half the cost of the AN/SPS-10F. To achieve this figure requires a MTBF of greater than 315 hours and an MTTR of two hours or less. The Modular Type IV predicted values are less than one-half hour MTTR and 750 hours MTBF. ARINC has stated that this empirical curve is valid only for MTBFs in the range of 94 to 2014 hours and MTTRs from 2.1 hrs to 5.9 hrs. While the Modular Radar predictions fall outside that allowable range, it is apparent that, even using these limits, more than a two-for-one improvement in LCC should be realized. An interesting observation from the curve of figure 25 is that, beyond about 500 hours MTBF and less than about one-half hour MTTR, there is an area of diminishing returns.

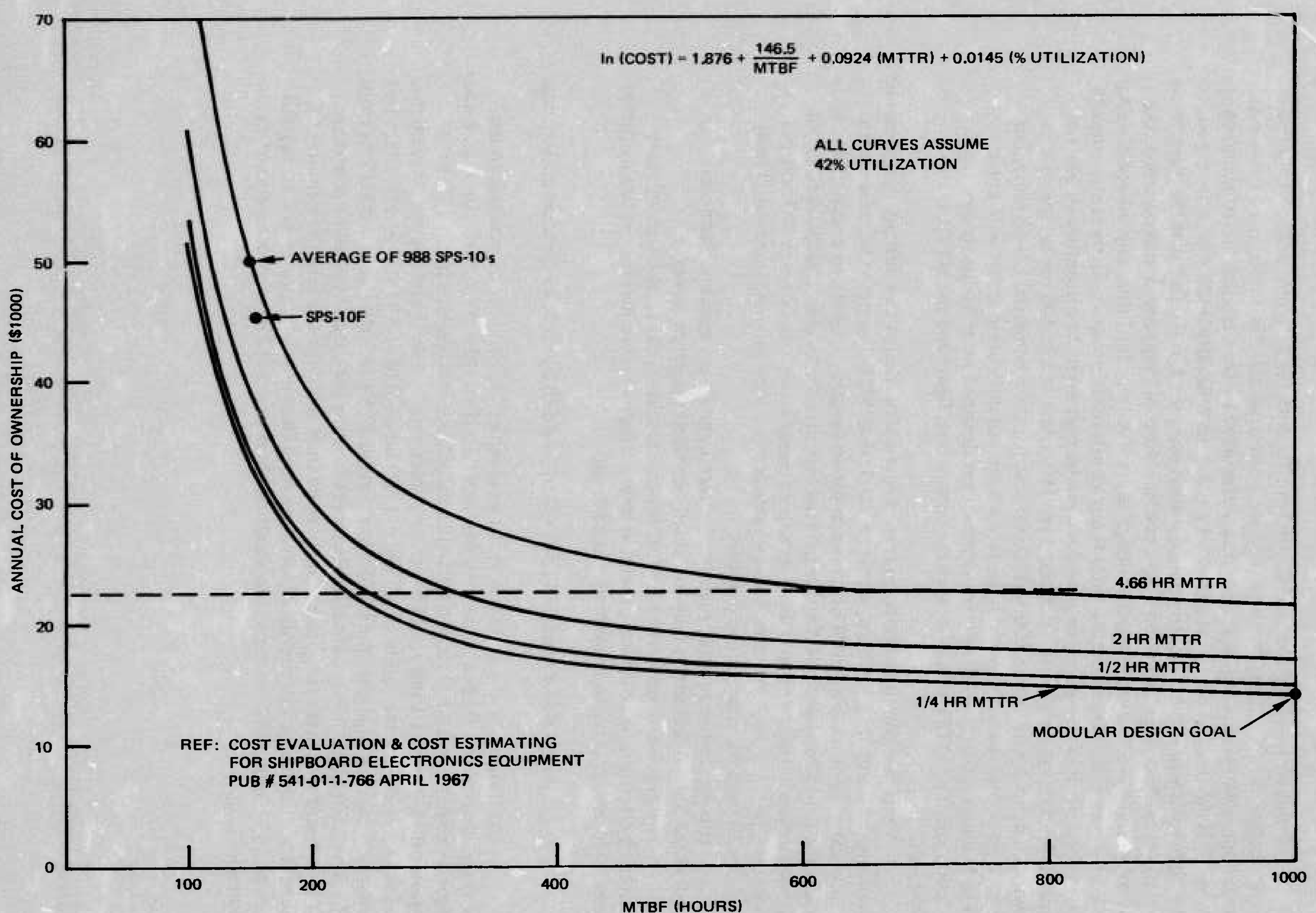

Figure 25. Radar systems cost evaluation.

OTHER MODULAR RADAR PROGRAMS

AIR FORCE WEATHER/BEACON NAVIGATION RADAR

During the early phase of the modular radar project, the U.S. Air Force became interested in the modular concept through a briefing given to them at Wright-Patterson Air Force Base by NELC and NAFI engineers. The Air Force initiated its own program to design an airborne modular radar, utilizing the same modules as the Navy, to replace the existing AN/APN-59 vacuum-tube system.

The program is currently underway at AFAL and NAFI and is scheduled to realize hardware delivery in February 1976 with test completion by September 1976.

AIR FORCE TACTICAL WEATHER RADAR

Late in calendar year 1974, NELC was visited by LT. COL. J. J. Morris, USAF, Systems Program Director, Weather Instrumentation SPO, Code OCT, Hanscom Field, Massachusetts. The purpose of the visit was to discuss a problem the Air Force was having in obtaining a radar system for "bare base operation."

His task was to set up air base operations in a location having no facilities except for a runway. To fulfill this task, he needed a weather-detection radar. No system existed which would meet his requirements within his budget. During the discussion, the modular radar concept was presented.

Subsequently, LT. COL. Morris has entered into a project with NAFI to demonstrate the feasibility of using essentially the modular Type I C-band radar for USAF purposes. The project began in November 1974 and calls for delivery of a demonstration unit in November 1975. If the project proves to be feasible, six of such systems will be built for field evaluation.

CONCLUSIONS

The 2175 Modular Radar Program has successfully completed its original objective of showing the feasibility of building surface-search radar systems in a modular format having a high degree of commonality leading to reductions in life-cycle costs.

Originally the program did not include the fabrication of entire radar systems. It was intended only to build those portions wherein there was reasonable technical doubt, such as in the solid-state modulator for use with a coaxial magnetron. However, the decision to use the Navy SEMs (then SHP) and the excellent working relationship obtained between NAFI and NELC has led to the construction of the entire family of radars and to savings of at least one year in whatever direction the program takes from this point.

RECOMMENDATIONS

In addition to the evaluation phase already scheduled, it is recommended that an ongoing program within the modular radar project be initiated to accomplish important tasks and projects.

SUPPORT FOR NAVSEA RADAR PROGRAM

NAVSEA 0652, under LCDR Boyle, has initiated a program to use the work started in the 2175 Modular Radar Project to produce modular radar systems to fill the Navy requirements in Types II, III, and IV classifications (now termed Class B systems). A need still exists in the Type I (Class A) area and NAVSEA 0652, under A. Bartolomei, is putting together a two-phase program which will also make use of the modular format. The first phase would be an interim system using as many SEMs as are practical to fill the immediate needs to replace the ailing AN/SPS-10s. The second phase would be to continue the development of the 2175 Type I, C-band radar (and/or the X-band) to reflect the new radar operational requirement issued by OPNAV.

LONG-TERM TASKS

It is recommended that a program be initiated to explore the feasibility of the following long-term developments:

1. Determine radar requirements and system parameters to meet high-speed craft needs in an environment of debris.

2. Define and design a processor to meet needs for collision avoidance, periscope detection, surface-target tracking and similar functions.

3. Investigate cost-effective, electronically scanned antennas suitable for collision avoidance and small-boat radars.

4. Investigate methods of achieving low-flyer detection and all-weather, surface-search and navigation with a single radar.

5. Investigate transmitter requirements to achieve pulse-to-pulse frequency agility.

6. Continue the development of improved modules for modular radars, such as low-noise pre-amplifier, improved BITE, strip-line assemblies, and front ends.

SHORT-TERM TASKS

For the near term the following items should be investigated.

1. Identify modular design and/or tube parameters which will have the capability of commonality regardless of operating frequency.

2. Determine a cost-effective method for performing mean-level detection (GON-VCS at operating pulse lengths of 0.1 microsecond or less).

3. Determine advantages and disadvantages of linear and logarithmic versus linear/logarithmic (LIN/LOG) i-f amplifiers.

4. Determine suitable methods of performing the IFF function for small craft.

5. Determine the feasibility of extending modulation design to accomplish a 50-nanosecond transmitted pulse.

6. Determine the feasibility of incorporating a weapons-system handover capability.

7. Investigate the feasibility of developing a one-megawatt S-band transmitter to be used with the modular family for the purpose of weather penetration.

OTHER RADAR SYSTEMS

The feasibility of using common SEMs has been demonstrated in the 2175 Modular Radar project and this concept should be extended to the air-search two-dimensional (2-D) and three-dimensional (3-D) radars and weapons-control radars. Certainly the microwave manifold concept is also applicable to other radar systems as are power supplies, timing and control circuits, and video circuits. There is no apparent reason why families of these radars cannot also be constructed with SEMs to realize the benefits outlined in this document for surface-search systems.

It is conceivable that the operational requirements of these radars may not be amenable to SEM implementation. However, it appears that, at least, significant portions could use SEM circuitry and it is recommended that a program be initiated to investigate this possibility.

The full potential of cost savings using SEMs while shown to be worthwhile in just the surface-search radar alone, will be even greater as more and more electronic systems are designed using Standard Electronic Modules.

REFERENCES

1. Chief of Naval Operations OPNAV Instruction 09670.2A, Ch. 1, Ship Type Electronics Plan, 1 October 1972.

2. Naval Electronics Laboratory Center Technical Report 1911, Project 2175 Phase I Report, March 1974.

3. Office of Naval Material NAVMAT Instruction 4120.102B, Standard Electronic Module Program (SEM) (undated draft).

4. Life-Cycle Cost Estimate for Surface-Search Radar Utilizing the SEM Concept, EG&G Washington Analytical Services Inc., May 1975.

5. Cost Evaluation and Cost Estimating for Shipboard Electronic Equipment, ARINC Research Corporation, April 1967.

6. Naval Sea Systems Command NAVSEA Research Paper 11R4-74, Economic Escalation Index for Defense Electronic Systems, 6 November 1974.

7. Naval Ship Systems Command, NAVSHIPS Engineering Bulletin 843, 11 December 1972.

8. NAVSECNORDIV Report 14-73, 2D/3D Radar Equipments MCDS and CASREPT, RM and A Indices for Surface Ships, 9 November 1973.

APPENDIX A

SURFACE-SEARCH RADAR SEM COMMONALITY WITH NAVY SYSTEMS

TABLE A-1. SURFACE-SEARCH RADAR SEM COMMONALITY WITH NAVY SYSTEMS.

SYSTEM	BBA	BDL	BYF	CMH	FHA	GDJ	GVQ	HRH	JDB	KDC	KDL	KDR	LDN	PDL	QQA	RBF	UMU	YBZ
AN/BQG-2A, 4? PUFFS				√														
AN/BQH-6	√	√								√			√					
AN/BQN-17 SONAR	√	√	√							√			√					
AN/BQQ-5 SONAR		√		√							√	√	√					
AN/BQQ-6 SONAR	√	√			√						√	√	√			√		
AN/BQR-21 SONAR				√									√				√	
AN/BQR-15 SPAD	√	√							√	√			√					
AN/BQS-4 SCAN SW.									√									
AN/BQS-11,12,13, SCAN SW.							√		√									
AN/BQS-13 MPS	√	√		√						√	√		√					
AN/SQN-17		√				√						√		√		√		
AN/SQS-26 SCAN SW.									√									
AN/SQS-4 SCAN SW.									√									
AN/SQS-35,38 SCAN SW.									√									
AN/SQS-17 SCAN SW.									√									
AN/SQS-23 SCAN SW.									√									
AN/SQS-56	√	√											√					
AN/ALR-60		√		√						√			√					
MK88 FCS				√														
MK98 FCS		√	√	√					√			√	√	√		√		
MK116/1 TORPEDO FC		√		√									√					
MK3, 7 MTRE		√	√			√		√					√					
SAWS DIG. PROC.		√		√		√						√		√				
SAMAC	√	√	√				√					√	√		√			
ESGM	√	√				√					√		√				√	
HARPOON SIMULATOR				√														√
WDE				√														
AWS		√											√					

APPENDIX B

SEM MODULES

TABLE B-1. LISTING OF APPROVED SEM MODULES.

Key Code	Description (4-2-75)	I_c	I_x	II	III	IV	Air Force
AEA	Voltage Scaler	1	1	1	1		1
AEC	Time Delay	1	1	1	1	1	1
AEH	A/D D/A Conv.	1	1	1	1		1
AFD	Trigger Driver	2	2	2	2	1	2
AHF	Optical Isolator	7	7	7	7	2	
AJB	Voltage Scaler					1	
AJG	Rotary Switch	1	1	1	1		
BBA	Bin. Up/Down Count.	1	1	1	1		1
BDL	Dig. Multiplexer	7	7	7	7		5
BYF	Ram (1024)	2	2	2	2		2
CDJ	H.V. LC Filter	1	1	1	1	1	1
CEP	Input O/V Protection	2	2	2	2	2	2
CFF	Video Buffer	5	5	5	5	1	2
CFG	STC Waveform Gen.	1	1	1	1	1	1
CGK	AC Filament Program	1	1		1		1
CGL	Driver	4	4	3	4	3	4
CMH	Test Point	8	8	8	8	5	8
EAB	Pull up Resistor	5	5	5	5	1	4
EEC	Modulator Voltage Select	1	1	1	1	1	1
EGA	RC Filter/Diode	2	2	3	2		2
EHP	Power Failure Reset	1	1	1	1		1
EHQ	Clock Driver	1	1	1	1		1
EHR	Microprocessor Interface	1	1	1	1		1
FAQ	Op-AMP Module	3	3	3	3	3	3
FAR	Output OC/OV Protection	3	3	3	3	3	3
FEG	H.V. Series Reg.	3	3	3	3		3
FEH	Sample & Hold	1	1	1	1	1	1
FFE	L.V. Pos. Series Reg.	6	6	6	6	1	6
FHA	Bin. Counter	8	8	8	8	3	5
FKP	STC Select	1	1	1	1	1	1
GAE	Triple Switch	1	1	2	1	2	1
GAF	L.V. Neg. Series Reg.	1	1	1	1	1	1
GBD	FTC/Video Select	4	4	4	4	2	2
GRJ	Latch	3	3	3	3		3
GVQ	Xtal Osc. (12.288 MHz)	1	1	1	1	1	1
GZB	Bus Buffer	4	4	4	4	1	2
HRH	Microprocessor	1	1	1	1		1
JDB	Mag. Comparator	1	1	1	1		
KBB	Filter, Bandpass	1	1	1	1	1	
KBD	Pulse Buffer					1	
KDC	Multiplexer	4	4	4	4		
KDE	Post Amplifier	2	2	2	2	1	1
KDL	Dig Adder	1	1	1	1		

TABLE B-1. CONTINUED

Key Code	Description (4-2-75)	I_c	I_x	II	III	IV	Air Force
KDR	D Flip-Flop	5	5	5	5	3	5
LDN	Nand Gate	6	6	6	6		3
NQD	Analog Multiplexer	8	8	8	8		10
PDL	Shift Reg.	2	2	2	2		2
QQA	File Reg.	2	2	2	2		
RBA	Clock/Ramp Gen.	2	2	2	2	2	2
RBB	AFC Module	1	1	1	1	1	1
RBF	Nand Gate	20	20	20	20	6	15
REC	Comparator	4	4	3	4	3	4
RKM	ROM (Reprogrammable)	5	5	5	5		7
UMU	LED Display	2	2	2	2		2
YBZ	Tri-State Buffer	5	5	5	5	1	
NOT YET ASSIGNED	Mixer Terminator	1	1	1	1		1
	32 X 8 ROM	1	1	1	1	1	2
	AFC Amplifier	1	1	1	1	1	1
	AGC Module	1	1	1	1		1
	L.V. LC Filter	3	3	3	3	2	3
	SYS Power Converter (DC)					1	
	SYS Power Converter (AC)	1	1	1	1		1
	AUX Power Supply (DC)					2	
	AUX Power Supply (AC)	2	2	2	2		2
	+5V Rec/Fil (10A)	1	1	1	1	1	
	+5V Rec/Fil (15A)						1
	Shorting Plug					2	
	Power Output Rect/Fil			1		1	
	Fil. Output Rect/Fil			1		1	
	XMIT Power Conv.					1	
	Modulator Iso. LC Filter			1		1	
	Low Power Chg. Network			1		1	
	Low Power PFN			1		1	
	HI Power Chg. Network	1	1		1		
	HI Power X PFN		1		1		
	HI Power C PFN	1					
	XMIT Power Conv.			1			
	AC Fil Sense	1	1		1		1
	HI Power XMIT Power Conv.	1	1		1		
	L.O. Series Reg.	1	1	1	1	1	1
	D/A Converter	2	2	2	2		2

APPENDIX C

MODULE COMMONALITY BETWEEN 2175 MODULAR RADAR SYSTEM AND TACTICAL WEATHER RADAR SYSTEMS

MODULE COMMONALITY BETWEEN 2175 MODULAR RADAR AND TACTICAL WEATHER RADAR SYSTEMS

The following is a list of the modules being used in three of the 2175 designs. Modules are listed by functional groups. The Prime Search refers to the 2175 Type I-C system, the Precision Navigation to the 2175 Type III and the Small Boat Navigation to the 2175 Type IV. The cost estimates assume a pilot production run of 25 units. The reliability prediction data are the published failure rates of Standard SHP (SEM) modules. The reliability estimates were made on all modules that do not have reliability prediction data. The estimates were made by comparing the module designs to modules of similar complexity and technology. The status refers to:

STD Standard Qualified SHP Module

IP In-Process Standard SHP Module

ND New Development SHP Module (Developed on Module Radar Program)

NA Not an SHP Module

The Tactical Weather Radar (TWR) is a C-band radar system similar to the 2175 Type I C-band. TWR is being developed for the Air Force ESD (Engineering Systems Division). The modules starred (*) in the list are used in the TWR system.

TABLE C-1. TIMING AND CONTROL GROUP.

One (1) additional module type required for the Timing and Control group for TWR.

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
GVQ	12.288 MHz Clock	1*	1	1	1A	$.28 \times 10^{-6}$	–	$ 50	STD
GYC	Read Only Memory	4	1	1	1A	1.89×10^{-6}	–	$175	IP
FHA	Counter (STTL)	10*	4	4	1A	–	1×10^{-6}	$125	IP
RBF	2-In NAND (STTL)	6*	6	6	1A	$.534 \times 10^{-6}$	–	$ 80	IP
LDN	3 & 4 In NAND (TTL)	2*	1	1	1A	$.56 \times 10^{-6}$		$ 75	STD
PDL	Shift Reg (TTL)	2*	1	1	1A	1.14×10^{-6}	–	$ 46	STD
–	Pull-Up Resistor	2*	2	2	1A	–	$.5 \times 10^{-6}$	$100	ND
–	D/A Converter	1*	1	–	1A	–	1×10^{-6}	$125	ND
GQB	Bus Buffer	2*	2	2	1A	–	$.5 \times 10^{-6}$	$100	ND
BDL	8:1 Multiplexer	1*	1	–	1A	2.0×10^{-6}	–	$ 44	STD
UMU	Digital LED Monitor	3*	3	–	1A	1.76×10^{-6}	–	$100	STD
–	Optical Isolator	10*	4	2	1A	–	1×10^{-6}	$150	ND
KHR	Flip-Flop (STTL)	1*	1	1	1A	–	1×10^{-6}	$ 80	IP
KDL	Adder (TTL)	1*	1	1	1A	1.13×10^{-6}	–	$ 80	STD
STT	Scott-T Transformer	1	–	–	1C	–	1×10^{-6}	$250	IP
SHY	MSB Function Gen.	1	–	–	1A	–	2×10^{-6}	$340	IP
SHU	LSB Function Gen.	1	–	–	1A	–	2×10^{-6}	$285	IP
SHV	Octant/Quad Converter	1	–	–	1A	–	2×10^{-6}	$310	IP
SHX	Error Detector	1	–	–	1B	–	2×10^{-6}	$350	IP
GDM	Counter	1	–	–	1A	1.88×10^{-6}	–	$150	STD
–	Time Delay Mod.	1*	1	1	1A		1×10^{-6}	$100	ND

TABLE C-1. CONTINUED

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
CMH	Test Point Mod.	2*	2	–	1A	$.456 \times 10^{-6}$	–	$ 30	STD
–	Peak Detector	3*	3	–	1A	–	2×10^{-6}	$150	ND
–	LM 161 Comparator	1*	1	1	1A	–	2×10^{-6}	$125	ND
–	Video Buffer	2*	2	1	1A	–	2×10^{-6}	$100	ND
–	FTC/Video Switch	1*	1	1	1A	–	2×10^{-6}	$150	ND
NQD	PRAM (BITE)	1*	1	–	1A	–	2×10^{-6}	$125	ND
–	Lin/Log Switch	1	1	–	1A	–	1×10^{-6}	$125	ND
–	Trigger Driver	2*	2	1	1A	–	1×10^{-6}	$125	ND
–	Input Buffer	1*	1	–	1A	–	2×10^{-6}	$125	ND
	Associated Hardware:								
	Cable Connector	4	4	2	1A	–	1×10^{-6}	$ 40	NA
	Card Cage (25X3)	1	–	–	–	–	–	$960	NA
	Card Cage (20X3)	–	1	–	–	–	–	$770	NA
	TOTAL								
	Prime Search	67			74		83.4×10^{-6}	$9,766	
	Small Boat Navigation			27	29		27.2×10^{-6}	$2,866	
	Precision Navigation		44		47		54.4×10^{-6}	$5,595	

TABLE C-2. PROCESSOR GROUP.
(This group will not be used in the TWR.)

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
JBN	One Shot	2	–	–	1A	–	1×10^{-6}	$100	IP
RDH	ALU (STTL)	4	–	–	1A	–	1×10^{-6}	$150	IP
QQA	Multi-port Reg.	4	–	–	1A	–	1×10^{-6}	$150	IP
JDB	Comparator (TTL)	1	–	–	1A	–	1×10^{-6}	$ 80	STD
PDL	Shift Reg. (TTL)	1	–	–	1A	1.14×10^{-6}	–	$ 46	STD
RBF	2-In NAND (STTL)	1	–	–	1A	$.534 \times 10^{-6}$	–	$ 80	IP
LHH	3 & 4 In NAND (STTL)	1	–	–	1A	–	$.5 \times 10^{-6}$	$ 80	IP
CMH	Test Point Mod.	1	–	–	1A	$.456 \times 10^{-6}$	–	$ 30	STD
NQD	PRAM (BITE)	1	–	–	1A	–	2×10^{-6}	$125	ND
–	Video Buffer	2	–	–	1A	–	2×10^{-6}	$100	ND
	Associated Parts:								
–	Sample/Hold & D/A & A/D Converter	1	–	–	–	–	10×10^{-6}	$1,000	NA
–	Delay Line	2	–	–	–	–	2×10^{-6}	$ 60	NA

TABLE C-2. CONTINUED

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
–	Cable Connectors	1	–	–	1A	–	$1 X 10^{-6}$	$ 40	NA
–	Card Cage (10X3)	1	–	–	–		–	$385	NA
	TOTAL	18			19		$34.6 X 10^{-6}$	$3,526	

TABLE C-3. BITE GROUP.

(No additional module types required for the BITE group for TWR.)

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
HRH	Microprocessor	1*	1	–	1A	–	$2 X 10^{-6}$	$300	IP
–	μ Processor Interface	1*	1	–	1A	–	$1 X 10^{-6}$	$125	ND
RPM	Reprogram ROM	3*	3	–	1A	–	$1 X 10^{-6}$	$150	ND
BYF	RAM	2*	2	–	1A	–	$2 X 10^{-6}$	$125	IP
BDL	8 : 1 Multiplexer	3*	3	–	1A	$2.0 X 10^{-6}$	–	$ 44	STD
GDJ	Latch	2*	2	–	1A	$1.79 X 10^{-6}$	–	$ 80	STD
–	A/D Converter	1*	1	–	1A	–	$2 X 10^{-6}$	$175	ND
RBF	2-In NAND (STTL)	2*	2	–	1A	$.534 X 10^{-6}$	–	$ 80	IP
GVQ	12.288 MHz Clock	1*	1	–	1A	$.28 X 10^{-6}$	–	$ 50	STD
NQD	PRAM (BITE)	3*	3	–	1A	–	$2 X 10^{-6}$	$125	ND
PDL	Shift Reg. (TTL)	1*	1	–	1A	$1.14 X 10^{-6}$	–	$ 46	STD
GQB	Bus Buffer	2*	2	–	1A	–	$.5 X 10^{-6}$	$100	ND
CMH	Test Point Mod.	1*	1	–	1A	$.456 X 10^{-6}$	–	$ 30	STD
–	Pull-Up Res.	1*	1	–	1A	–	$.5 X 10^{-6}$	$100	ND
	Associated Hardware:								
–	Cable Connector	4	4	–	1A	–	$1 X 10^{-6}$	$ 40	NA
–	Card Cage (10X3)	1	1	–	–	–	–	$385	NA
	TOTAL Prime Search & Precision Navigation	24	24		28		$36.1 X 10^{-6}$	$3,098	

TABLE C-4. RECEIVER GROUP.
(Four (4) additional module types required for the Receiver group for TWR.)

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
CMH	Test Point Mod.	1*	1	1	1A	$.456 \times 10^{-6}$	–	\$ 30	STD
RBF	2-In NAND (STTL)	1*	1	1	1A	$.534 \times 10^{-6}$		\$ 80	IP
–	Post Amp Lin/Log	2*	1	1	2B	–	2×10^{-6}	\$300	ND
–	AFC Amp w Desc	1*	1	1	2B	–	2×10^{-6}	\$300	ND
–	BP Filter WB/NB	1	1	1	2B	–	2×10^{-6}	\$250	ND
–	STC Waveform Gen.	1*	1	1	1A	–	2×10^{-6}	\$125	ND
–	STC Select Mod.	1*	1	1	1A	–	1×10^{-6}	\$150	ND
–	AGC Module	2	1	1	1A	–	2×10^{-6}	\$125	ND
–	Sample/Hold CKT	2*	1	1	1A	–	2×10^{-6}	\$150	ND
–	Volt. Scaling Network	1*	1	1	1A	–	1×10^{-6}	\$100	ND
NQD	PRAM (BITE)	1*	1	–	1A	–	2×10^{-6}	\$125	ND
–	BITE Sig. Cond.	1*	1	–	1A	–	2×10^{-6}	\$125	ND
–	FTC Module	1*	1	1	1A	–	2×10^{-6}	\$125	ND
	Associated Hardware:								
–	Cable Connector	1	1	–	1A	–	1×10^{-6}	\$ 40	NA
–	Card Cage (10X3)	1	1	–	–	–	–	\$385	NA
	TOTAL								
	Prime Search	18			29		27.8×10^{-6}	\$2,985	
	Small Boat Navigation			11	20		18.8×10^{-6}	\$1,735	
	Precision Navigation		15		23		23.8×10^{-6}	\$2,410	

TABLE C-5. POWER SUPPLY GROUP.
(No additional module types required for the Power Supply Group for TWR.)

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
CMH	Test Point Mod.	1*	1	1	1A	$.456 \times 10^{-6}$	–	\$ 30	STD
–	HV Series Reg.	1*	1	1	1A	–	5×10^{-6}	\$125	ND
–	LV Neg. Series Reg.	1*	1	1	1C	–	5×10^{-6}	\$200	ND
–	LV Pos. Series Reg.	4*	4	2	1C	–	5×10^{-6}	\$200	ND
–	HV Rectifier/Filter	1*	1	1	1B	–	5×10^{-6}	\$150	ND
–	LV Rectifier/Filter	3*	3	2	1C	–	5×10^{-6}	\$175	ND
–	Comparator	1*	1	1	1A	–	2×10^{-6}	\$100	ND
–	OP Amp. Mod.	1*	1	1	1A	–	2×10^{-6}	\$150	ND
–	Clock/Ramp Gen.	1*	1	1	1B	–	2×10^{-6}	\$175	ND
–	Input O/U Volt. Prot.	1*	1	1	1A	–	2×10^{-6}	\$100	ND
–	Output I/V Prot.	1*	1	1	1A	–	2×10^{-6}	\$100	ND

TABLE C-5. CONTINUED

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
–	Power Transformer/ Transistor & Input Rect/Filter (AC)	1*	1	–	2G	–	$20 X 10^{-6}$	$350	ND
–	Aux. Power Supply (DC)	–	–	1	1E	–	$10 X 10^{-6}$	$225	ND
NQD	PRAM (BITE)	1*	1	–	1A	–	$2 X 10^{-6}$	$125	ND
–	Aux. Power Supply (AC)	1*	1	–	1E	–	$10 X 10^{-6}$	$225	ND
–	Transistor Driver	1*	1	1	1B	–	$2 X 10^{-6}$	$125	ND
–	Power Transformer/ Transistor & Input Diode (DC)	–	–	1	2G	–	$20 X 10^{-6}$	$350	ND
	Associated Hardware:								
–	Cable Connector	2	2	1	1A	–	$1 X 10^{-6}$	$ 40	NA
–	CARD Cage (20 X 3)	1	1	–	–	–	–	$770	NA
	TOTAL								
	Prime Search	20			58		$96.5 X 10^{-6}$	$4,130	
	Small Boat Navigation			16	47		$78.5 X 10^{-6}$	$2,620	
	Precision Navigation		20		58		$96.5 X 10^{-6}$	$4,130	

TABLE C-6. TRANSMITTER GROUP

(An additional PFM is required in the Transmitter group for TWR due to the pulse width requirements.)

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediciton (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
CMH	Test Point Mod.	1*	1	1	1A	$.456 X 10^{-6}$		$ 30	STP
NQD	PRAM (BITE)	1*	1	–	1A		$2 X 10^{-6}$	$125	ND
–	PRAM Det. (BITE)	1*	1	–	1A		$2 X 10^{-6}$	$125	ND
–	Trig. Generator	2*	2	2	1B		$5 X 10^{-6}$	$150	ND
–	LV Pos. Series Reg.	2*	2	2	1C		$5 X 10^{-6}$	$200	ND
–	Aux. P. S.	1*	1	1	1E		$10 X 10^{-6}$	$225	ND
–	Ramp/Clock Gen.	1*	1	1	1B		$2 X 10^{-6}$	$175	ND
–	OP Amp. Mod.	2*	2	2	1A		$2 X 10^{-6}$	$150	ND
–	Comparator	3*	2	2	1A		$2 X 10^{-6}$	$100	ND
–	Driver	3*	2	2	1B		$2 X 10^{-6}$	$125	ND
–	Mod. Volt. Sel.	1*	1	1	1A		$2 X 10^{-6}$	$125	ND
–	Input O/U Volt.	1*	1	1	1A		$2 X 10^{-6}$	$100	ND
–	Output 1V/ Prot.	2*	2	2	1A		$2 X 10^{-6}$	$100	ND
–	PWP. XFMR/XISTORS & Line Rect/Filter (Special for each magnetron)	2*	1	1	2G		$20 X 10^{-6}$	$350	ND

TABLE C-6. CONTINUED

Key Code	Function	Number Used: Prime Search	Precision Navigation	Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost Unit	Status
–	FIL XFMR/XISTORS & Line Rect/Filter (Special for each magnetron)	1*	–	–	2G		20×10^{-6}	$350	ND
–	Modular Isolation LC Filter (Special for each magnetron)	1*	1	1	1D		5×10^{-6}	$200	ND
–	PWR Output Rect/Filt. (Special for each mag.)	2*	1	1	1B		5×10^{-6}	$200	ND
–	Fil Output Rect/Filt. (Special for each mag.)	1*	1	1	1C		5×10^{-6}	$200	ND
	Associated Parts:								
–	Cable Connector	4*	4	4	1A	–	1×10^{-6}	$ 40	NA
–	Low Power PFN	–	1	1	–	–	5×10^{-6}	$250	NA
–	High Power-C PFN	1	–	–	–	–	10×10^{-6}	$325	NA
–	LP Charging Network	–	1	1	–	–	10×10^{-6}	$200	NA
–	HP Charging Network	1*	–	–	–	–	20×10^{-6}	$300	NA
–	Magnetron LP-X	–	1	1	–	–	250×10^{-6}	$400	NA
–	Magnetron C	1*	–	–	–	–	250×10^{-6}	$600	NA
–	Card Cage								
	25 X 3	1	–	–	–	–	–	$960	NA
	20 X 3	–	1	1	–	–	–	$770	NA
	6 X 3	1	1	1	–	–	–	$190	NA
	Mounting Plate	1	–	–	–	–	–	$ 85	NA
	Mounting Plate	–	–	–	–	–	–	$ 85	NA
	TOTAL:								
	Prime Search	28			92		424.5×10^{-6}	$7,250	
	Small Boat Navigation			21	59		356.5×10^{-6}	$5,310	
	Precision Navigation		23		57		360.5×10^{-6}	$5,560	

TABLE C-7. MICROWAVE GROUP.

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
–	C-Band Noise Source	1*	–	–	–	–	10×10^{-6}	$300	–
–	Waveguide Switch	1*	–	–	–	–	1×10^{-6}	$150	–
–	C-Band Mixer	2*	–	–	–	–	1×10^{-6}	$300	–
–	Gunn Oscillator	1*	–	–	–	–	10×10^{-6}	$400	–
–	Mixer Diode	2*	–	–	–	–	200×10^{-6}	$ 15	–
–	TR Limited	1*	–	–	–	–	100×10^{-6}	$300	–
–	Phase Shift Circulator	1*	–	–	–	–	20×10^{-6}	$400	–
–	IF Pre-Amp	2*	2	2	–	–	10×10^{-6}	$200	–
–	X-Band Noise Source	–	1	1	–	–	10×10^{-6}	$300	–
–	X-Band Mixer	–	2	2	–	–	1×10^{-6}	$300	–
–	Oscillator	–	1	1	–	–	10×10^{-6}	$400	–
–	Mixer Diodes	–	2	2	–	–	200×10^{-6}	$ 15	–
–	FDL	–	1	1	–	–	50×10^{-6}	$300	–
–	Circulator/Filter	–	1	1	–	–	10×10^{-6}	$400	–
–	μWave Manifold	1	1	–	–	–	–	$2,000	–
–	μWave Mounting		–	1	–	–	–	$100	–
–	Interconnections	–	–	1	–	–	–	$600	–
–	Interconnections	1	1	–	–	–	–	$500	–
	TOTAL:								
	Prime Search	13					563×10^{-6}	$5,080	
	Small Boat Navigation		12				502×10^{-6}	$3,130	
	Precision Navigation			12			502×10^{-6}	$4,930	

TABLE C-8.. SYSTEM GROUP.
(Enclosure design will be different for the TWR.)

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
–	Local Control	1	–	–	–	–	–	$900	–
–	Remote Control	1	–	–	–	–	–	$300	–
–	Cabinet	1	–	–	–	–	–	$4,000	–
–	Cooling System	1	–	–	–	–	–	$2,000	–
–	Cabling	1	–	–	–	–	–	$500	–
–	Control Box	–	–	1	–	–	–	$600	–
–	42 X 3 CARD Cage	–	–	1	–	–	–	$1,540	–
–	Cabinet	–	–	1	–	–	–	$2,500	–
–	Cooling System	–	–	1	–	–	–	$400	–
–	Cabling	–	–	1	–	–	–	$400	–

TABLE C-8. CONTINUED

Key Code	Function	Number Used: Prime Search	Number Used: Precision Navigation	Number Used: Small Boat Navigation	Size	Reliability Prediction (Failure/Hr)	Reliability Estimate (Failure/Hr)	Estimated Pilot Production Cost/Unit	Status
–	Control Box	–	1	–	–	–	–	$700	–
–	Cabinet	–	1	–	–	–	–	$1,735	–
–	Cooling System	–	1	–	–	–	–	$450	–
–	Cabling	–	1	–	–	–	–	$500	–
	TOTAL:								
	Prime Search							$7,700	
	Small Boat Navigation							$5,440	
	Precision Navigation							$3,385	

APPENDIX D

2175 MODULAR RADAR DESIGN GOALS, TYPE I

SPECIFICATION FOR
2175 MODULAR RADAR, TYPE I

1.0 SCOPE

1.1 SCOPE

These design goals shall be in effect throughout the development phase of the 2175 Modular Radar Program.

1.2 OBJECTIVE

This program shall encompass the development of brassboard radars to be used to test the modularity philosophies developed under the program leadership, and the development of design specifications. The modularity philosophy shall be advanced to the greatest degree practicable.

1.2.1 CLASSIFICATION

The radar described herein as a C- or X-band, surface-search and navigation radar for use aboard Navy major combatant ships and hereby shall be defined as a Type I radar. It shall consist of the following:

Transmitter Group } C- or X-band
Microwave Group }
Receiver Group
Timing/Control Group
Processor Group
Power Supply Group
BITE Group

1.3 ASSOCIATED EQUIPMENT

The equipment shall operate with the following associated items which are not defined as a part of this paper:

Antenna	AN/SPS-10 (C-band) or AN/SPS-55 (X-band)
Display	AN/SPA-25

The equipment shall be operated by an internal control panel or by a remote control box.

2.0 APPLICABLE SPECIFICATIONS

2.1 GENERAL

A. MIL-E-16400 "Electronic Equipment, Naval ship and shore; General Specification."

B. Other specifications to be determined.

3.0 REQUIREMENTS

3.1 GENERAL

This radar shall have the capability of a 2:1 reduction in life cycle cost as compared to an equivalent existing radar (e.g. AN/SPS-10 or AN/SPS-55).

3.1.1 PARTITIONING

This radar shall be partitioned as described below:

COMPONENT – One piece, or two or more pieces joined together which are not normally subject to disassembly without destruction of designed use.

MODULE – Two or more components joined together to perform a specific function and capable of disassembly or replacement as a whole.

SECTION – An assembly or any combination of components and modules mounted together, normally capable of independent operation in a variety of situations.

GROUP – A collection of sections, modules or components defined as a subdivision of an operational function. It may be designed as a set subfunction or may be designed to be added to or used in conjunction with a set to extend the function or utility of the set.

SET – A collection of groups, sections, modules and components connected together or used in association to perform an operational function.

3.1.2 COMMONALITY

This radar shall be partitioned and constructed to achieve modularity and commonality at all levels. Each level of partitioning shall be considered a modular entity possessing the following qualities:

Accessability

Repairability

Reliability

Commonality in part or in total with modular entities, other radar sets or other equipments

Standardization

3.2 DESIGN AND CONSTRUCTION

The equipment shall conform with all applicable requirements of specifications Mil-E-16400 for design, construction and workmanship, except as otherwise specified herein.

3.2.1 TOTAL WEIGHT

The total weight of the equipment shall be a minimum consistant with good designs and shall not exceed 250 pounds, excluding cables.

3.2.1.1 GROUP WEIGHT. The weight of a circuit group shall not exceed 30 pounds.

3.2.2 RELIABILITY

3.2.2.1 RELIABILITY IN MEAN-TIME-BETWEEN-FAILURES (MTBF). The mean (operating) time between failures shall be not less than 500 hours, when operating in the ship's environment.

3.2.2.2 ELAPSED TIME METER. The equipment shall contain elapsed time meters. As a minimum requirement, meters shall be included in the following two groups in a totally accessible location for reading particularly when the groups are installed in the radar set:

Transmitter (for transmitter time)

Power Supply (for total system time)

3.2.2.3 OPERATING LIFE. The equipment shall have a minimum total operating life of 50,000 hours with reasonable servicing and replacement of parts.

3.2.2.3.1 OPERATION STABILITY. The equipment shall operate with satisfactory performance continuously or intermittently for a period of 240 hours in the shipboard environment without the necessity for readjustment of any controls which are inaccessible to the operator during normal use.

3.2.3 NOMENCLATURE AND NAMEPLATES

Nomenclature assignment and nameplate approval for equipment identification shall be made with the approval of NELC.

3.2.4 STANDARD CONDITIONS

The following conditions shall be used to establish normal performance characteristics under standard conditions and for making laboratory bench tests:

Temperature	Room Ambient (25 ± 5°C)
Altitude	Normal Ground
Vibration	None
Input Power Voltage	115 ± 1.0 VRMS (3Ø, 60 Hz)

3.2.5 SERVICE CONDITIONS

The equipment shall operate satisfactorily under the environmental service conditions specified in MIL-E-16400.

3.2.5.1 COOLING. Heat removal methods shall be in accordance with MIL-E-16400.

3.2.6 PRIMARY INPUT POWER REQUIREMENTS

The equipment shall maintain specified performance characteristics when operating with any of the following power sources of which the limits and transients shall be defined by MIL-STD:

Preference	Input Power Type	Applicable Standard
1st Choice	115 VRMS, 3Ø, 60 Hz, Delta	MIL-STD-1399-Section 103
2nd Choice	115 VRMS, 3Ø, 400 Hz, Delta	MIL-STD-1399-Section 103
3rd Choice	115 VRMS, 3Ø, 400 Hz, WYE	MIL-STD-704

3.2.6.1 AC FREQUENCY. In general, equipment shall operate over the primary input power frequency range of 57 to 420 Hz ± 5%.

3.2.7 STANDBY AND WARM-UP PROVISIONS

A 'warm-up' mode shall be incorporated in the equipment in order to prevent the magnetron from being activated inadvertently prior to reaching cathode operating temperature. 'Warm-up' shall be initiated whenever the equipment is sequenced from OFF to ON. It shall last 5 minutes and prevent high voltage from being applied to the magnetron. During the 'warm-up' mode, power will be applied only to the magnetron filament and other system components. After 5 minutes has passed, the equipment automatically shall enter the standby mode with an appropriate panel indication. Standby is the normal non-transmitting mode from which the transmit mode can be activated at will.

3.2.8 CABLES AND CONNECTORS

Cables and connectors shall be in accordance with MIL-E-16400 unless otherwise specified herein. Specific approval of NELC shall be obtained for cables and connectors not listed in MIL-E-16400. Connectors shall be used in lieu of removable blank plates and stuffing tubes. Reliability, standardization and commonality shall be the primary considerations in selecting connectors.

3.2.8.1 Cables carrying (A) ac power and (B) digital or commutative signals with their respective returns shall be run separately from all other cables and connectors.

3.2.9 INTERFERENCE CONTROL

Equipment shall be designed to conform with MIL-STD-461, MIL-STD-469 and/or any more preferable standards or procedures under the direction of NELC. As a minimum requirement, the rf transmitter shall be electrically isolated from all other circuits by having its own independent power supply. It shall also be mechanically isolated from all other circuit packaging.

3.2.10 MAINTENANCE PROVISIONS AND FIELD TESTING

Verification of the maintenance philosophy shall be made during the tests described in paragraph 4.2.

3.2.10.1 MALFUNCTION LOCATION. The BITE display shall indicate any out-of-tolerance faults, with a 95% confidence level, to a group of four or five modules. A sequential module replacement method shall be used to locate the faulty module or modules within that group. This procedure is designed to be independent of personnel skill level.

3.2.10.2 THROWAWAY. Modules shall be designed to support the throwaway concept. Exceptions shall be approved by NELC.

3.2.10.3 MEAN-TIME-TO-REPAIR (MTTR). The modules shall be designed for quick removal and replacement. The total time for repair is as follows, less decision-to-repair, spare acquisition, and equipment warm-up times:

MTTR	5 min (goal)
MTTR	15 min (max)

3.2.10.4 SPARES. In-rack storage of spares shall be given consideration. Provisioning of life-time spares with equipment also shall be given consideration.

3.3 PERFORMANCE

Unless otherwise specified, values set forth to establish the requirements for satisfactory performance apply to performance under both standard and service conditions.

3.3.1 GENERAL

The radar set described herein shall be an advanced developmental model (ADM), i.e. a brassboard, capable of demonstrating improvements in equipment life cycle cost while maintaining performance requirements. The Navy Standard Hardware Program (SHP) shall be the basic approach to modularity. New modular concepts shall be mechanized in the spirit of SHP and be capable of demonstrating a high degree of commonality with other modular radar types.

3.3.2 OPERATION

This ADM radar set and all controls thereof shall be capable of safe, reliable and easy operation in a variety of conditions as follows:

- A Laboratory bench
- B Mobile Military Equipment van stationed at NAFI
- C Van based on NELC shoreline
- D Limited ship installation

3.3.3 SYSTEM PERFORMANCE

The radar set shall match or exceed the performance of the radar set AN/SPS-10 at C-band and the AN/SPS-55 at X-band while providing input data to NELC for a life cycle cost analysis.

3.3.4 SYSTEM INPUTS

3.3.4.1 POWER

(A) 115 VRMS, 3Ø, 60 Hz, Delta

3.3.4.2 ANTENNA

(A) WR 187 Waveguide
(B) Heading Marker
(C) Synchro Signals
(D) Man Aloft Signal

3.3.4.3 OTHER

(A) External Trigger (SPA-42)

(B) Ship's Compass Synchro Signals

3.3.5 SYSTEM MODES

3.3.5.1 POWER ON/OFF. Power shall be applied to all groups. In the timing/control group, a 5 minute timer will be initiated to hold-off activation of the transmit mode whenever the equipment is sequenced from OFF to ON. After the timer has counted 5 minutes, the equipment automatically will switch to the standby mode. ON remains illuminated on control panel whenever switch is engaged.

3.3.5.2 STANDBY. This mode shall be the normal or preferred non-radiating mode and should be used for BITE troubleshooting and other maintenance activities. The transmit mode can be entered from this mode at will. STBY is illuminated.

3.3.5.3 TRANSMIT. Transmit shall be the normal radiating mode where high voltage pulses are applied to the magnetron. This mode is allowed only after timer in paragraph 3.3.5.1 has counted 5 minutes. This mode shall never be entered automatically, e.g., when modes switch automatically from on to STBY. XMIT is illuminated on control panel.

3.3.5.3.1 SECTOR RADIATE. Controls shall be provided to set what portion of the antenna's 360° azimuthal coverage will be used for transmitting and receiving. The minimum coverage shall be $22\text{-}1/2^{\circ}$ centered at any of 16 evenly spaced bearing positions. A NORMAL control position shall represent full 360° coverage.

3.3.5.4 SILENT. This mode shall be considered an ECM mode, i.e., absolutely no radiation. It can be initiated at any time; power to all groups will be disrupted except that the transmitter group's magnetron filament supply and the power group's internal/auxiliary supply for necessary controls will stay intact. The ON/STBY modes will automatically accompany the silent mode to indicate the status of the magnetron cathode temperature. SILENT is illuminated on panel.

3.3.6 DETAILED PERFORMANCE

A	Frequency	C- or X-band
B	Peak Power	175 kW (C-band) or 130 kW (X-band)
C	Pulsewidth	0.1/1.0 μsec

D	PRF	4000/1000 Hz
E	System Noise Figure	10 dB
F	Rcvr Bandwidth	12/1.2 MHz
G	Rcvr Processing	LIN/LOG or LOG only STC/AGC Clutter Rej
H	I-f Center Frequency	60 MHz
I	MTBF	500 hr (min)
J	MTTR	5 - 15 min
K	Input Power	115V, 60 Hz, 3ϕ

3.4 DETAILED DESIGN REQUIREMENTS

3.4.1 MODULARITY

The radar set shall use SHP modules as the basic design with emphasis on:

(1) Inter System Module Commonality

(2) Intra System Module Commonality

(3) Maximum use of existing modules

(4) Minimum number of special modules

(5) The spirit of SHP shall be retained throughout the entire set.

3.4.2 TRANSMITTER GROUP

3.4.2.1 GENERAL DESCRIPTION. The transmitter shall use a solid state magnetic switching modulator packaged in the SHP format. Two separate, but mechanically interchangeable, transmitter groups shall be constructed to meet the requirements of C- or X-band operation. Both shall transmit either of two pulse widths with electronic switching in each modulator. The transmitter characteristics are defined in specification number 89199-0007004.

3.4.3 MICROWAVE GROUP

3.4.3.1 GENERAL DESCRIPTION. The Microwave Group shall make the greatest use of new solid state components, primarily to improve circuit reliability. The packaging shall retain the spirit of SHP. Two separate, but mechanically interchangeable, microwave groups shall be constructed to meet the requirements of C- or X-band operation. The microwave characteristics are defined in specification number 89199-0007005.

3.4.4 RECEIVER GROUP

3.4.4.1 GENERAL DESCRIPTION. The receiver shall contain a single bandpass shaping module, thus allowing control of bandwidth by module replacement, pin programming and/or the control logic. The receivers and associated circuits shall be designed for universal usage. The receiver characteristics are defined in specification number 89199-0007009.

3.4.5 TIMING/CONTROL/PROCESSOR GROUP

3.4.5.1 GENERAL DESCRIPTION. This group shall be designed for universal usage and growth. The characteristics are defined in specification number 89199-0007006.

3.4.6 PROCESSOR GROUP

3.4.6.1 GENERAL DESCRIPTION. This group shall be designed for universal usage and growth. The characteristics are defined in specification number 89199-0007006.

3.4.7 POWER SUPPLY GROUP

3.4.7.1 GENERAL DESCRIPTION. This group shall be designed for universal usage. The characteristics are defined in specification number 89199-0007007.

3.4.8 BITE GROUP

3.4.8.1 GENERAL DESCRIPTION. The BITE circuits shall accept conditioned voltages from the BITE modem located in each of the groups, process these signals in a microcomputer and generate malfunction data to within four of five modules. BITE characteristics are defined in specification number 89199-0007008.

3.4.9 PACKAGING

Package design shall be consistent with the requirements concerning provisioning and construction described heretofore. The design concept is intended to be innovative and optimized for the following:

A Modularity/SHP

B Commonality/Interchangeability

C Reliability

D Accessibility/Repairability/Maintainability

Only general constraints shall be enforced in order to allow as much freedom of design as possible. Those constraints are:

A Maximum Size – 10 cubic feet

B Cooling – Forced air; conduction, convection or radiation.

C Weatherproofing – Drip-proof and salt resistant

D Shock – MIL-E-16400 as guideline.

E Vibration – MIL-E-16400 as guideline.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 QUALITY CONTROL

The supplier shall be responsible for the in-process quality control of the radar set.

4.1.1 SYSTEM BURN-IN

The supplier shall accumulate on the radar set a minimum of 40 hours of standby and test operation. The power supply elapsed time meter shall serve as the record.

4.2 CLASSIFICATION OF TEST

The radar set shall be subjected to the following tests:

1 Workmanship Test

2 Shore Tests

3 Limited Ship Test

4 Life Cycle Cost Analysis

4.2.1 WORKMANSHIP TESTS

The supplier shall conduct workmanship tests as outlined as follows:

1 Complete final visual inspection

2 Vibration 0 - 20,000 Hz

3 Eight hour burn-in tests

4.2.2 SHORE TEST

The purchaser shall have prime responsibility and supplier shall support the van-mounted radar during the shore tests.

4.2.3 LIMITED SEA TESTS

The purchaser shall have prime responsibility and the supplier shall provide support to the radar set during these tests.

4.2.4 LIFE CYCLE COST ANALYSIS

The supplier will provide certain engineering data, as agreed upon by NELC, to a contractor for life cycle cost analysis. Data from shore and ship test will be available to support this analysis.

5.0 PREPARATION FOR DELIVERY

5.1 GENERAL

Delivery shall be made as agreed upon with NELC.